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A TEXT-BOOK OF SURGERY

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VOLUME I

THE PRINCIPLES OF SURGERY
AND SURGICAL PATHOLOGY

WITH FIVE HUNDRED AND SIXTEEN ILLUSTRATIONS

NEW YORK
D. APPLETON AND COMPANY
1901

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PREFACE TO VOLUME I.

Since the first English translation of the third German edition of this volume, seven years ago, four new German editions have appeared. The alterations and additions made necessary in the latter by recent progress, chiefly in pathology and bacteriology, have been so numerous that a second English edition is now urgently required.

The division of text-books of surgery into separate volumes on general and regional topics, which was first practised exclusively by German and French writers, has now become the custom in English and American works. Such an arrangement is a result of the great advances that have been made of late in surgical pathology and bacteriology, and of the growing appreciation of the value of these fundamental principles to the student and practitioner of surgery. It is important that our medical students should have a text-book from which they can first gain a thorough knowledge of the principles of surgery before taking up surgical diseases and injuries of special parts. Furthermore, the surgeon of to-day, who wishes his work to be fruitful of the best results, must keep pace with the advances in the fundamental sciences underlying his art.

The present volume contains not only a complete exposition of general surgical pathology and bacteriology, but also chapters on diseases and injuries of special tissues, with their treatment; tumours; general surgical technique, and bandaging. This arrangement leaves for the two following volumes the application of the principles already learned, and the systematic description of the surgical diseases and injuries of the different regions.

The favourable reception given to the work in this country will, it is hoped, be extended to this new edition, from which much that was obsolete has been eliminated, and to which have been added the results of the latest researches in surgical pathology and the most modern development of general surgical technique.

Benjamin T. Tilton.

59 West Thirty-sixth Street.

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TILLMANNS' PRINCIPLES OF SURGERY AND SURGICAL PATHOLOGY.

FIRST SECTION.

GENERAL PRINCIPLES GOVERNING SURGICAL OPERATIONS.

CHAPTER I.

THE PREPARATIONS FOR AN ASEPTIC OPERATION.

a. Definition of a surgical operation. *b.* The indications and counter-indications for undertaking an operation. *c.* Antisepsis and asepsis. *d.* The preparations for an aseptic operation.—Operating room.—Operating table.—Preparation of the patient, the operator, and his assistants.—Sterilisation of the instruments, sponges, gauze pads, etc.—Preparation of aseptic dressings.

§ 4. **Definition of a Surgical Operation.**—An "operation," in the broadest sense of the word, means any mechanical interference of the surgeon undertaken with a view to remedy disease, in which interference surgical instruments are used.

A distinction is made between an operation in which a loss of blood occurs and one in which it does not. To the bloodless operations belong, for instance, the introduction of a catheter into the bladder, the crushing of a vesical calculus by the lithotrite, the removal of foreign bodies from the external auditory meatus, from the pharynx, etc. But, generally speaking, an operation is ordinarily understood to be of the kind that is accompanied by a loss of blood, and this is the kind that is meant here.

"Operative surgery," says Dieffenbach, "is, of all branches of the healing art, the most suited to arouse enthusiasm in its followers; it is a bloody fight with disease for life—a fight that means life or death." Every surgeon must have a certain amount of natural talent, and an enthusiastic devotion to his profession. A complete mastery of the technique, keen senses, a well-trained eye, a delicate touch, and a steady hand, are all indispensable. The plan of the operation must be

clearly thought out beforehand, and during the operation must be quietly and resolutely carried out.

§ 5. **Indications and Counter-indications for an Operation.**—A difficult problem which often confronts the surgeon is to correctly weigh the indications and counter-indications for undertaking an operation. It is often a hard question to decide whether a cure is not possible without an operation; and it is well to consider whether the proposed operation does not carry with it greater dangers than the disease itself, especially in those cases where the annoyances are but slight. The counter-indications for operation depend upon the particular organ which is diseased or upon the general condition of the patient (extreme youth or old age, general weakness, coexisting acute or chronic disease, etc.). Under all circumstances it is necessary to have the consent of the patient for the proposed operation.

The question as to whether an operation should be performed against the will of the patient is answered differently by different surgeons, though the majority of physicians consider that they are entitled, and indeed obliged, in exceptional cases, to perform an operation against the will of the patient—if, for instance, the danger from the operation is much less than that from the continuation of the disease, or if the patient can be saved by the operation from certain death.

To gain the desired end in such cases—or, in other words, to perform the operation—the patient is chloroformed, and upon recovering from the anæsthetic he is usually glad that the operation has been done, even though contrary to his will.

§ 6. **Preparations for an Antiseptic or Aseptic Operation.**—We operate, without exception, according to either antiseptic or aseptic principles—that is, we try to prevent entrance into the wound of substances that tend to cause inflammation and putrefaction. All the decomposing products of putrefaction come under the head of septic matter—sepsis (from σῆψις) meaning putrefaction. An *antiseptic* operation is one in which antiseptic solutions are used to kill the bacteria that may be present in the wound or enter it during the course of the operation. An *aseptic* operation is one in which everything that is to come in contact with the wound is rendered previously germ free, and no antiseptics are used during the course of the operation. The bacteria that cause infection of wounds exist everywhere; they float in the air, where they are mixed with the atmospheric dust, they cling to the clothes and the skin of the patient and the operator, they are found on the instruments, sponges, etc. Therefore, if we wish to protect those upon whom we operate from the noxious influence of bacteria, we must take the greatest pains to keep the latter out of the wound,

or, if they have already found lodgment in the body, to check their further development, and to destroy them as soon as possible.

The preparations for an aseptic operation must be so managed that every possibility of infecting the wound is avoided. Hence we must always take pains to most rigidly disinfect the operating room, the table, the part to be operated upon, the hands and clothes of the operator and his assistants, the instruments, sponges, and dressings—in short, everything which comes into direct or indirect contact with the wound.

Antisepsis and Asepsis.—During operations in former times, antiseptics were employed much too freely—for instance, in the form of a mist, the so-called spray, or in the form of irrigations—and at the close of the operation the wound was once more energetically disinfected. Our most effective antiseptics, especially carbolic acid and bichloride of mercury, are poisonous, and many patients have died after the operation of carbolic and bichloride poisoning. The too intense irritation of antiseptics endangers the vitality of the tissues with which they come in contact, and renders them less capable of withstanding bacteria; furthermore, serious parenchymatous lesions, particularly of the kidney, are thus produced in operations within the thoracic and peritoneal cavities. It is right, therefore, to limit the use of antiseptics in operations; in fact, most surgeons aim to avoid them entirely. Disinfection and antiseptic treatment of a fresh wound which has been made by the surgeon is not necessary if the operation is conducted strictly aseptically—that is, if the field of operation, the hands of the surgeon, the instruments, the sponges or gauze pledgets, etc., have been sterilised—i. e., rendered free from micro-organisms. If irrigation is desirable, a sterilised solution of common salt of a strength of five tenths to seven tenths per cent., or boiled water, should be substituted for the carbolic or bichloride solutions. If larger amounts of sterilised water are needed, the apparatus of Fritsch is useful. The employment of a six-tenths-per-cent. sterilised salt solution is especially useful in laparotomies.

Asepsis has taken the place of antisepsis in operations, for the reason that a wound which has not been irritated by antiseptics heals much more readily, the secretion is much less, and drainage can more frequently be entirely dispensed with. Furthermore, the process of repair in the wound is quicker with the aseptic than with the antiseptic method; the aseptic cicatrix forms sooner, and is more solid and durable than when the wound has been irritated by antiseptics. When the latter have been used the process of cell division is more sluggish, and begins later.

In the case of wounds treated by the aseptic method, complete healing and the formation of the cicatrix usually occupies eight days; while in wounds in which bichloride of mercury has been used the change from granulation to cicatricial tissue has hardly begun in this time.

Socin, Bergmann, Neuber, and others, were among the first to give up antisepsis for asepsis, though Lawson Tait and Koberle had long furnished proof that beautiful operative results could be obtained without using antiseptic solutions. But for injuries and wounds already infected, the rules of rigorous antisepsis are to be carried out—i. e., the wound should be thoroughly disinfected with a three- to five-per-cent. solution of carbolic acid or one tenth to one fiftieth per cent. of bichloride of mercury. I am, however, of the opinion that it is not possible to really disinfect, with our usual antiseptic solutions, a wound that has once become infected. The bacteria present in the tissues are not acted upon sufficiently by the antiseptics—i. e., they are not killed. The chief requirement in infected wounds is to provide for sufficient escape of the infected secretions by incision and drainage. Moreover, it is no longer the custom to use dressings that have been impregnated with bichloride or carbolic acid. They are much more easily and surely sterilised by steam. Dressings impregnated with antiseptics are often found after a time to contain bacteria. Steam sterilising apparatus have now been universally introduced in hospitals for the treatment of dressings, operating gowns, beds, bed-clothing, etc., and small steam sterilising apparatus can easily be brought into every large surgical ward. The portable steam sterilisers of Straub, H. Settegast, Bubenberg, E. Hahn, and Schimmelbusch are especially adaptable for private practice. In Fig. 1 is illustrated the steriliser of Schimmelbusch. As regards the mechanism of this apparatus, the following should be noted: *W*, the part which holds the water, is filled by a funnel through the tube *T*, up to a marked height. Whatever is to be sterilised is placed in the inner compartment of the apparatus, the latter having a double metallic wall. The cover *D* is screwed on tight. In the centre of the cover is placed the thermometer, *Th*. The water is heated by a gas flame, and the

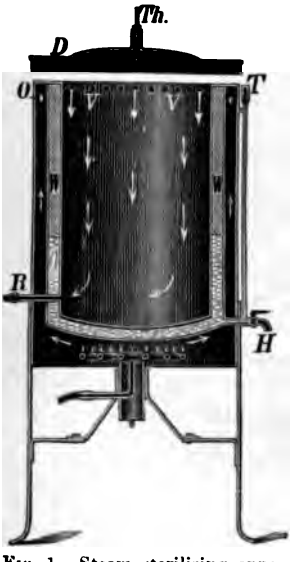

Fig. 1.—Steam sterilising apparatus (Schimmelbusch).

steam, at a temperature of 100° to 130° C. (212° to 266° F.), enters the inner compartment of the apparatus from above, and escapes through the opening *R* into a lead spiral in a condenser filled with water. The air between the double-walled water vessel and the metallic enclosure, which is protected by asbestos, escapes through the openings at *O*. At the end of the sterilisation the water can be drawn off through the faucet *H*, the cover is removed, and the sterilised article taken out. In order that the sterilised dressings can be kept sterile, the tin vessel devised by Schimmelbusch (Fig. 2) is used. This is provided with a tight cover (*d*) and a great number of holes (*a b*); the latter can be opened and closed at will by a strip of tin. This tin vessel is filled with dressings and placed in the steriliser.

Fig. 2. — Sheet-iron vessel for dressing materials (Schimmelbusch).

We shall return again to the subject of sterilisation of the dressings, operation gowns, compresses, etc., and presently describe the sterilisation of the instruments by boiling for five minutes in a one-per-cent. soda solution, the cleansing of the hands, etc. For the disinfection of large articles, such as mattresses, clothes, etc., the disinfector of Rietschel and Henneberg is particularly good. In order to be sure that the temperature in the steriliser reaches a sufficient height, different appliances have been made use of. For example, a bell is attached which rings when the temperature reaches 130° C., or small glass tubes containing crystals of phthalic acid, or alloys of lead, zinc, and bismuth, which melt at a temperature of 110° C., are inserted.

Fig. 3.—Stand for solution bottles.

Strehl is right in recommending that sterilisers which are heated by gas, and are used in the operating room or its vicinity, should be supplied with an arrangement for carrying off the gas, in order that the air in the operating room may not be contaminated by the harmful gases, and the danger of decomposition of the chloroform (see page 27) may be avoided.

The cleanliness of the operating room and of everything it contains must always be rigorously enforced by the surgeon.

Operating Room.—The operating room should be as light as possible, well ventilated, and plentifully supplied with arrangements for washing, receptacles for disinfecting solutions, especially three- to five-per-

cent. solutions of carbolic, bichloride (1 to 1,000–5,000), alcohol, and sterile salt solution.

Iron stands for the solution bottles, such as the one shown in Fig. 3, are very useful.

In larger hospitals it is well to have two operating rooms, one for aseptic operations and the other for infected cases; and it is advantageous to have on the floor of the operating room, which is best made of cement, a gutter arrangement for conducting off the water.

The walls of the operating room must be so built as to be capable of being easily and thoroughly cleansed, and therefore should be covered with oil or enamel paint, or with metal or glass plates. Recesses

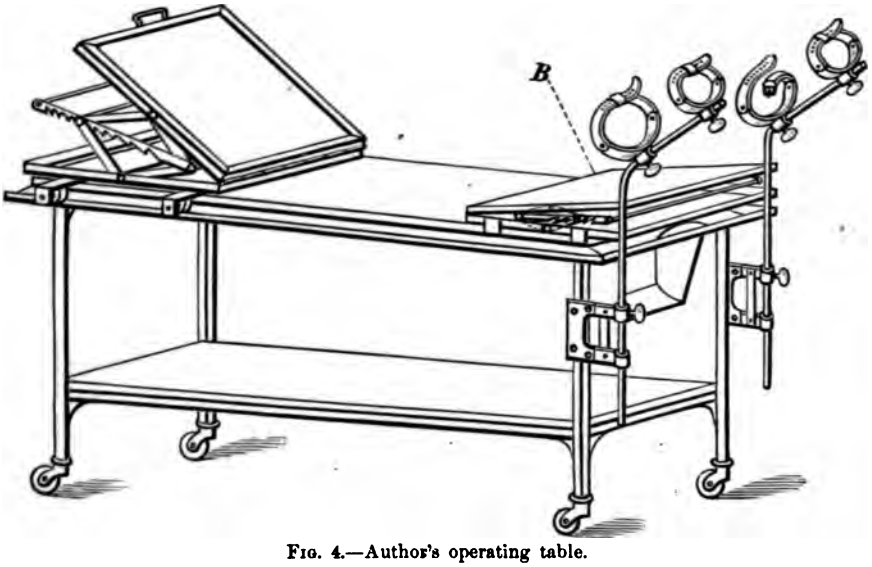

Fig. 4.—Author's operating table.

and corners which can harbour dust, etc., are to be avoided, on account of the microbes they contain, and pains should be taken not to stir up dust either before or during the operation. Before an operation the air in the room can be moistened by steam from a large spray or steam pipe, if there is one, and thus freed of dust.

Operating Table.—The operating table should be as simple as possible and absolutely clean. In order to facilitate the escape of soiled liquids, operating tables are coming more and more into use which are provided with means to carry off these fluids. Operating tables made with an iron frame and a glass plate are very good. My own operating table, illustrated in Fig. 4, has an iron frame with a plate of strong flint glass; the gutter placed around the table conducts away the overflow into a vessel underneath, and the whole table can be readily cleaned. The head-piece, which is easily adjusted, is

fitted with a removable glass plate. For elevating the pelvis, a movable framework can be brought into use, made, like the head-piece, of glass and iron, and leg-supporters can be very easily attached. I have also devised a transportable table with folding legs for private practice and for army use (Figs. 5, 6, and 7), which is made of wrought iron, weighs only twenty-five kilogrammes, and is inexpensive.

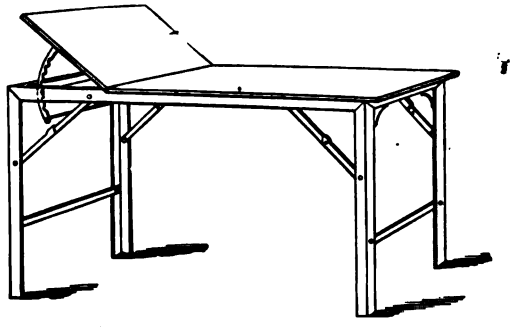

Fig. 5.—Author's transportable operating table for private and military practice.

Trendelenburg and others have constructed tables which allow the patient to be brought into various positions. The table invented by Knoke and Dressler (Figs. 8, 9, and 10) is an excellent one of this sort. For protracted operations—laparotomies, for instance—it is advantageous to use operating tables which can be kept warm, such as metallic tables (Socin) filled with hot water. In this way the patient is kept from losing too much body temperature.

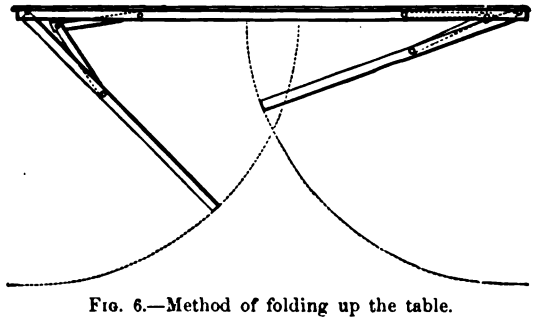

Fig. 6.—Method of folding up the table.

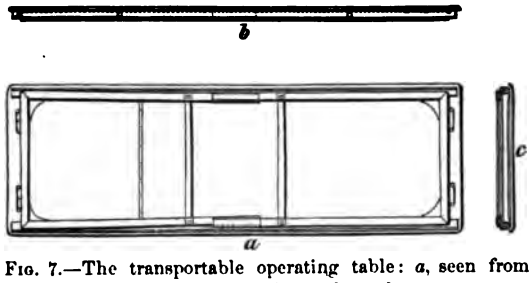

Fig. 7.—The transportable operating table: *a*, seen from below; *b*, the side; *c*, the end.

Preparation of the Patient. — The preliminaries for an operation begin with the preparation of the patient. In operations of any magnitude the whole body should be first thoroughly cleansed by means of a warm bath. The field of operation is then rendered aseptic in the most scrupulous manner. If this is not done properly the success of the operation is rendered doubtful and stitch-hole abscesses are very likely to occur, even when the sutures and needle are aseptic. The skin is scrubbed with tincture of green soap and warm water, shaved, rubbed off with ether in order to remove the fat on the skin and the micro-organisms that it contains,

and finally washed with a three- to five-per-cent. solution of carbolic or a bichloride solution of 1 : 1,000 to 5,000. The scrubbing and disinfecting of the hands and feet especially must be thoroughly and care-

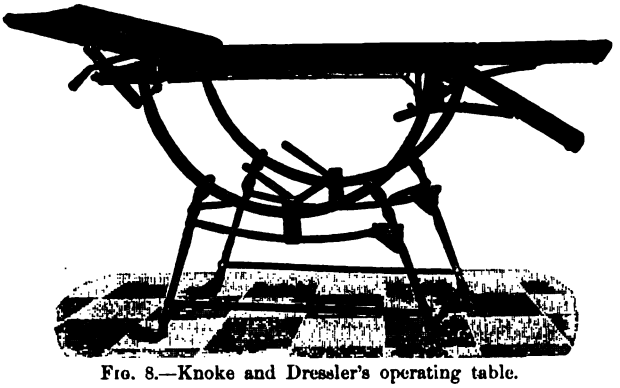

Fig. 8.—Knoke and Dressler's operating table.

fully carried out. Instead of brushes which are boiled and kept in a bichloride solution (1 to 1,000), I use swabs of wood fibre or cotton which are sterilised by heat and burned after use.

In operations in the mouth the teeth should be thoroughly cleansed by a toothbrush, and the mouth frequently rinsed with a chlorate-of-potash solution of a strength of 5 or 6 to 100, or permanganate of potassium, boric acid, etc. Carious teeth and

Fig 9.—Knoke and Dressler's operating table. Trendelenburg position.

Fig. 10.—Knoke and Dressler's operating table. Lithotomy position.

the tartar which swarms with bacteria, etc., are to be removed. If the operation is in the hypogastric region, in the neighbourhood of the anus, on the urinary and sexual organs, or in the peritoneal

cavity, care should be taken to secure a movement of the bowels on the last day before the operation by a dose of castor oil, and about two hours before the operation the rectum should be washed out with lukewarm water injected from an irrigator. When necessary, the bladder should be emptied in advance by a catheter.

Fig. 11.—Preparation of the patient for operations on the face and neck.

The stomach of a patient about to be chloroformed should, if possible, be empty, and in all cases the taking of solid food shortly before the operation should be forbidden, so that the respiratory movements of the diaphragm shall not be interfered with, and troublesome vomiting shall not occur. The entrance of vomited matter into the air-passages has repeatedly caused death during chloroform narcosis.

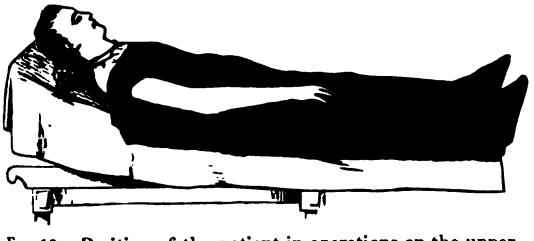

Fig. 12.—Position of the patient in operations on the upper extremity.

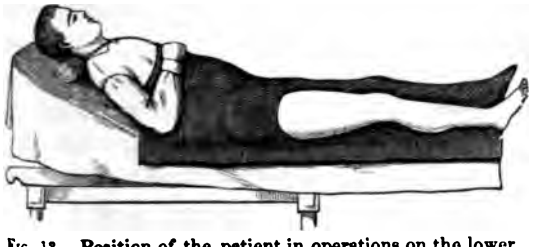

Fig. 13.—Position of the patient in operations on the lower extremity.

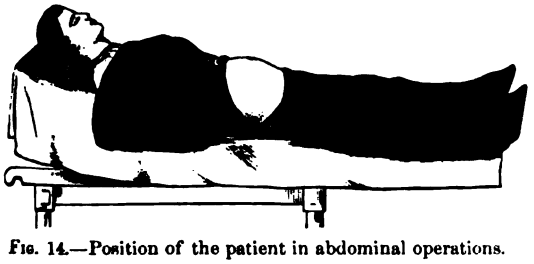

Fig. 14.—Position of the patient in abdominal operations.

After cleansing and sterilising the field of operation, I cover the same for several hours (if time permits) with a moist aseptic dressing of one-per-cent. formalin. At the time of the operation the patient is covered with rubber sheeting and sterile linen compresses, leaving the field of operation exposed (Figs. 11–14). For this purpose the protective coverings are provided with openings for the arms, legs, and neck, or they are suitably fastened together with safety pins. The linen protectives should be sterilised by keeping them for half an hour in the steriliser at a temperature of 100° to 130° C. The sterile

compresses about the field of operation may in addition be wrung out in 1-to-1,000 bichloride.

In operations upon the face and neck the patient's hair should be covered by a rubber cap, which is made to fit tightly by means of an elastic band, so as to prevent the hair from coming in contact with the field of operation; or, better still, the head may be wrapped in an aseptic gauze bandage.

For operations in the peritoneal cavity, it is better to provide two protectives, as is shown in Fig. 14. Figs. 11 to 14 illustrate sufficiently the excellent plan which has been recommended by Neuber.

If an operation is protracted, especially in cold weather, care must be taken that the patient does not become chilled. If the patient becomes badly chilled, a dangerous or even fatal collapse may be produced, especially after operations in the peritoneal cavity. For this reason it is wise to protect the patient by flannel coverings, warm cloths, etc., and particularly by warming the operating room to about 16°–18°–19° R. (68° to 75° F.). For protracted operations the warmed operating table of Socin, already mentioned, is valuable.

The best clothing for the operator and his assistants consists of a linen operating gown, the sleeves of which only reach to the middle of the upper arm. Before every operation the freshly washed operating gowns are sterilised for a half to three quarters of an hour in the steriliser by the action of hot steam at a temperature of 100° C. (212° F.). With a view to preserving thorough asepsis, the operator and his assistants must work with bare forearms.

Sterilisation of the Hands.—The hands and forearms are disinfected in the following manner: While dry, the nails are first cleansed of visible dirt by a nail cleaner and scissors which are always kept in a ten-per-cent. solution of carbolic acid in glycerine; then the hands and forearms are thoroughly scrubbed with a brush in soap and warm water, with special attention to the ends of the fingers and the part underlying the nails. The nailbrushes are sterilised by boiling and are kept in 1-to-1,000 bichloride. Coarse white or gray pumice stone may also be used for cleansing the hands. The latter are then rubbed with fifty-per-cent. alcohol, and before the latter evaporates the hands and forearms are scrubbed for two to three minutes in hot 1-to-1,000 bichloride, three-per-cent. carbolic acid, three-quarters-per-cent. creosol, or one-per-cent. formalin. Finally they are rubbed with a gauze compress moistened in 1-to-1,000 bichloride or one-per-cent. formalin. The bichloride may be removed by treating the hands with sulphide of ammonium and sterile water. It is of the greatest importance in disinfection of the hands to soften the skin thoroughly by means of

the warm water and to clean them mechanically with nailbrushes, so as to remove the bacteria that are present in the deeper layers, the glands, etc. Ether or alcohol are very useful in dissolving the fat on the skin and thus allowing the antiseptic solutions to act more effectually. Quite recently a number of tests have been made by Saul, Paul, Krönig, Fürbringer, Freyhan, and others to determine the antiseptic value of alcohol. These experiments have shown varying results. Most of the authorities have come to the conclusion that alcohol, when used in too concentrated a form, diminishes the action of the antiseptics such as bichloride, but that, on the other hand, weak alcoholic solutions (twenty-five to fifty per cent.) of antiseptics like bichloride, carbolic, lysol, and thymol are more efficacious than aqueous solutions of the same strength. Paul and Krönig found that the germicidal action of aqueous solutions of bichloride was increased by the addition of twenty-five per cent. ethyl alcohol or by methyl alcohol and acetone, while, on the other hand, the action of aqueous solutions of phenol and formaldehyde diminishes with every addition of ethyl alcohol or methyl alcohol. Absolute alcohol possesses no strength as a germicide, and the same is true of boiling absolute alcohol (Saul). It follows from this that in disinfecting the hands it is important not to use alcohol in too concentrated a form. If the hands are rubbed for one minute in fifty-per-cent. alcohol as described above and then placed in a large basin containing 1-to-1,000 bichloride, the germicidal action of the latter is certainly not diminished and is probably increased. In fact, I consider the use of diluted alcohol an important element in the success of my method of sterilisation of the hands. Krönig has had very good results with the following method of disinfecting the hands in his gynæcological clinic in Leipsic: After trimming and cleaning the nails and washing the hands and forearms for eight minutes in warm water, the hands and forearms are placed for three minutes in a solution containing one per cent. permanganate of potash and one half per cent. chlorine water. This solution is prepared as follows: 45 cubic centimetres of pure hydrochloric acid (German Pharmacopœia, twenty-five per cent.) are well mixed with 1,600 cubic centimetres of water, and to this 500 cubic centimetres of a four-per-cent. permanganate-of-potash solution are added. As this solution attacks metallic and enamelled vessels, wooden ones should be used. The hands and forearms are then decolourised in a warm 1.3-per-cent. solution of oxalic acid, and finally rinsed off in sterile water in order to lessen the irritating action of the oxalic acid. For keeping the hands in a good condition, Pears' glycerine soap is particularly useful, and, if anything more is necessary, the inunction of a small amount of lanolin is excel-

lent. Modern surgeons should give up wearing rings, and in any case always lay them aside before an operation, as they are invariably bearers of infection. I do not use the operating gloves made of rubber, linen thread, silk, etc., which have been recommended of late; or the mouth protectors used by Mikulicz. Why should we cover our hands, which have already been made sufficiently aseptic, with an organic material, such as the operating gloves, which, according to Döderlein, are more likely to become impregnated with bacteria than the hands themselves? In septic operations, however, and examinations of infected wounds, or in vaginal examinations, operating gloves are of use as a means of protection and should be used. In place of operating gloves Menge has recommended covering the hands with a sterilised solution of xylol in paraffine. In operations that must be performed under strictest asepsis, such as those in the peritoneal cavity, the operator and his assistants should talk as little as possible, because we have learned from Flügge's investigations that, in speaking, bacteria pass from the mouth in very small fluid particles, and are carried for some distance, thus causing infection. For this reason Mikulicz recommended his mouth protectors. A large basin containing a lukewarm antiseptic solution should be placed near the operator and his assistants, so that they may constantly keep their hands disinfected, even though they do not come in contact with unclean objects or with pus, fæces, urine, etc.

Sterilisation of Instruments.—The instruments are best disinfected by boiling them for five to ten minutes in a one- to two-per-cent. solution of soda, the latter substance rendering them less liable to rust than plain water. Crystalline soda should be used and not the kind adulterated with sulphate of soda or common salt. In order to prevent the instruments from rusting, Lévai recommends the addition of pure one-quarter-per-cent. caustic soda to the water and allows them to lie in this weak solution. They are much less likely to rust if placed in water that is already boiling, as the carbonic acid has then been expelled in great part from the water. The knives and needles are placed in a separate compartment in order that their edges may not be injured by contact with the other instruments. As wooden handles on instruments are soon damaged by boiling, nickel-plated metal handles are preferable.

Instruments are not sufficiently disinfected by simply placing them in carbolic or other antiseptic solution (Gärtner, Kümmel, Gutsch, Redard, Davidsohn). A sterilising apparatus for instruments can be made for a small price by any tinman, in the following manner: a large box made of sheet copper, with a removable top, is provided

with a tray of tin plate which is punched full of holes; the tray holds the instruments, and has two handles attached to it so that it can be lifted out after the boiling and placed in a three-per-cent. solution of carbolic acid. A very excellent apparatus, devised by Schimmelbusch, is illustrated in Fig. 15, but it is much more expensive. The figure needs no explanation. At the close of the process of sterilisation the wire tray *E*, which holds the instruments, is taken out and placed in three-per-cent. carbolic or sterile salt solution contained in a glass dish or tray made of enamel-covered metal.

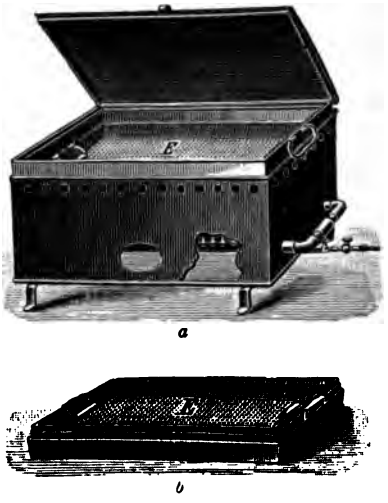

Fig. 15.—Apparatus for boiling instruments (Schimmelbusch).

Before using, I generally wipe off every knife carefully with a piece of sterilised cotton moistened in a three-per-cent. solution of carbolic acid. This is a mechanical means of disinfection which Gärtner has shown to be particularly efficacious. During the operation the instruments should lie in an antiseptic solution, such as three-per-cent. carbolic acid, one-half- to one-per-cent. creosol, or in sterile salt solution, or one- to two-per-cent. soda solution, or they are used dry. They are placed in trays made of glass, porcelain, and metal. The non-breakable and easily cleaned vessels of enamelled metal which are used in the kitchen are very good for this purpose. After every operation the instruments are scrubbed with a brush and soap in a three-per-cent. solution of carbolic acid and then polished.

Metallic catheters and sounds are sterilised like all metallic instruments by boiling them. Soft catheters and bougies are sterilised by subjecting them to steam from five to fifteen minutes, or to formalin, or hydrochloric acid vapour. They may also be sterilised by placing them for twenty-four hours in a three-per-cent. solution of formalin in glycerine, and then kept in glycerine. Catheters taken directly from the formalin solution must first be dipped before using in a non-irritating solution, such as glycerine. Lévai places the bougies and catheters before use in liquefied paraffine, which has a strong antiseptic action.

Among other sterilising apparatus, those of Braatz, Kronacher, Sternberg, Mehler, Klien, and Slomann should be mentioned. For

private practice and military surgery Kronacher, Turner, Lautenschläger, and others have devised transportable apparatus.

Sterilised Gauze Wipes.—For sponging the wound during the operation, gauze, or cotton balls wrapped in gauze, should be used. These wipes are sterilised by placing them for half an hour in the steam steriliser. They are decidedly preferable to ordinary sponges, as they are only used once, and are afterwards burned. A large stock of such gauze wipes can be always kept on hand in a bichloride solution (1 to 1,000), but it is better to use those that are freshly sterilised.

Disinfection of Sponges.—Ordinary sponges very quickly become useless after sterilisation in the hot steam of a steriliser, and they are best disinfected in the following way: After pounding them thoroughly, rinse them in a solution of potassium permanganate (1 to 500–1,000), then soak them for a quarter of an hour in a solution consisting of four fifths to one per cent. of hyposulphite of soda and from one fifth to eight per cent. of pure hydrochloric acid (Keller); then place them for a quarter of an hour more in boiling water or in a boiling soda solution of a strength of one per cent. The sponges are stored in a five-per-cent. solution of carbolic acid or one-tenth-per-cent. solution of bichloride of mercury.

Sterilisation of Dressings, Silk, Catgut.—Silk, catgut, drainage tubes, dressings, and bandages should also be rendered perfectly sterile. Silk should be boiled for half an hour in a bichloride solution (2 to 1,000) or a five-per-cent. carbolic solution, and the other materials can be treated by dry sterilisation—i. e., by keeping them in the dry steriliser for half an hour at a temperature of 100° to 130° C. For the sterilisation of catgut, see page 94.

The Spray.—Some years ago the operation and the application of the dressings were always carried out under the Lister spray—in other words, in a fine mist of carbolic acid. The management of the hand spray can be understood without further explanation from the illustration in Fig. 16. The steam spray apparatus consists of a vessel containing water, with a spirit lamp underneath. The boiler is filled through the opening at *a* and then closed by a stopper which is screwed in place. At *b* is placed a safety valve, which allows the steam collected in the kettle to escape in case the cock at *c* is turned off. The steam passes from the boiler through a tube closed and opened by the cock *c*, then into a glass containing three to five per cent. carbolic acid, and drives the latter out of the end of the tube in the form of a spray, the direction of which can be changed by means of the handle *d*.

At present the spray, as has been said, is seldom employed, and I, personally, never use it. It has been proved that the results obtained without the spray are just as good as those obtained with it. The spray is troublesome, inconvenient for the operator, and not free from danger to the patient on account of the not unimportant chilling it may cause, and from the danger

of carbolic or bichloride poisoning. I sometimes use the spray before a laparotomy when I wish to purify the air of the operating room, and for this purpose I use a steam spray placed as high up as possible. In hospitals fitted with steam or water pipes, a

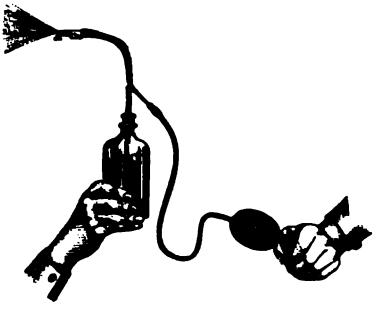

Fig. 16.—Hand spraying apparatus.

Fig. 17.—Steam spraying apparatus.

very effective spray apparatus can be contrived by connecting the steam pipe with the boiler of the apparatus, and in this way the air in the operating room can be very easily and cheaply rendered germ free—in other words, disinfected. This should be done after a clinic, for example, when an operation such as a laparotomy is to be performed in the same room. Removal of the dust in the operating room and wards by means of steam is very desirable, as the dust in these places contains microbes, which can give rise to infection.

Otherwise disinfection of the air of the operating room is not necessary, since, in general, wounds are only infected by contact with the microbes on unclean and insufficiently disinfected hands, dressings, and instruments, but not by the bacteria in the air (Kümmel, P. Fürbringer), provided the room is free from dust. I lay great stress upon covering the neighbourhood of the field of operation with sterilised towels dipped in a one-tenth-per-cent. solution of bichloride of mercury.

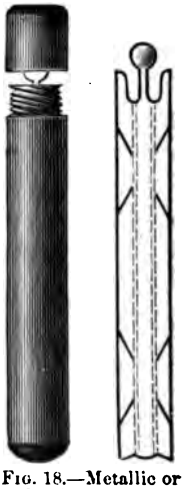

Fig. 18.—Metallic or hard-rubber case with spool for aseptic catgut and silk.

Preparation of the Dressings.—I should mention that the aseptic coverings of the wounds, dressings, bandages, etc.—sterilised by heating them at a temperature of 100° to 130° C.—are made ready in advance. We shall speak of these in Chapter II. (The Technique of applying Dressings).

Preparations for Operations in Private Practice.—If an operation is to be conducted aseptically outside of a clinic or hospital, as large and light a room as possible should be selected, and thoroughly cleaned and aired. The surest and simplest ways of disinfecting a room are to rub down the walls and ceiling with bread (E. von

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Esmarch), or to generate formalin vapour in Schering's apparatus, or to burn sulphur after closing off the room thoroughly. A table, on which to place the patient, should be provided, and covered with some water-tight material and then with sterilised linen; and two or three other tables should be near by, likewise covered with sterilised linen, to hold the instruments, dressings, and wash-basins.

Several wash-basins, soap, absolute alcohol, brushes, towels, sterilised dishes for the instruments, and sponges should be within reach, as well as warm sterilised water in large quantities, chloroform or ether, concentrated carbolic solution, tablets of bichloride, aseptic sponges or gauze pads, drains, silk, catgut, and the necessary instruments sterilised by boiling in a one-per-cent. soda solution, and dressings and bandages.

Silk and catgut can be carried about very easily in the simple apparatus pictured in Fig. 18.

CHAPTER II.

THE ALLEVIATION OF PAIN DURING OPERATIONS.—GENERAL AND LOCAL ANÆSTHESIA.

History.—Chloroform.—The physiological action and the method of administering chloroform.—Symptomatology of chloroform narcosis.—The possible accidents during chloroform narcosis: death from chloroform.—Treatment of the possible accidents during chloroform narcosis.—Other anæsthetics: methyl compounds.—Ether.—The phenomena of ether narcosis.—Method of administering ether.—The remaining ether compounds.—Nitrous oxide (laughing gas) as an anæsthetic.—Other anæsthetics.—Mixed narcosis.—Local anæsthesia.

§ 7. **The Alleviation of Pain during the Operation.**—A distinction is made between general anæsthesia—i. e., narcosis which is caused by the inhalation of some sleep-producing vapour or gas—and the local anæsthesia which is limited to a particular portion of the body, and produced by the local application of a substance to the part of the body to be operated upon.

Historical.—Since the earliest times attempts have been made to perform operations with the aid of some means for allaying pain, but the methods were invariably bad, and the action of the remedies which were tried was insufficient. It was not till the year 1846, with the introduction of ether as an anæsthetic, that the dream of the old surgeons was to come true—namely, the performance of even major operations without pain.

As early as the year 1800, Humphry Davy, reasoning from his numerous physiological experiments, had recommended nitrous oxide (laughing gas) as an anæsthetic; and Horace Wells, a dentist in Hartford, tested the remedy in 1844 by extracting twelve or fifteen teeth; but he was not able to introduce the drug as an anæsthetic into general surgical practice.

In ancient times cannabis indica and opium were the chief drugs for controlling pain. Besides these, the pulverised stone of Memphis was used—a kind of marble which, when treated with acetic acid, gives off carbonic acid and in this way produces a certain amount of local anæsthesia. Mandrake root, made into a decoction with wine, was also given internally, and was used especially by the ancient Greek physicians, and in fact was employed during the middle ages till the end of the sixteenth century. In the middle ages patients were often made to inhale vapours made from hemlock and from the juice of the mandrake leaf. Of interest in this connection are the experiments of Theodoric of Cervia, a learned Dominican, who at his death, in 1298, was Bishop of Bologna. A celebrated surgeon of Salerno, Mazzeo

not desirable to give morphine before.

della Montagna (1309–1349), is said to have given the patients whom he was about to operate upon some sleep-producing potion. Porta also speaks of a remedy, without describing it more exactly, which, when inhaled, brought on a deep sleep.

Besides these methods, excessive bloodletting till fainting occurred, compression of the vessels and nerves (Moore), enormous doses of tartar emetic, electricity, animal magnetism, and hypnotism have all been tried. On April 8, 1829, Cloquet is said to have removed without pain a cancer of the breast, together with the axillary glands, from a fourteen-year-old girl during the magnetic sleep, and in 1842 Ward amputated a thigh under the same conditions. Guérineau also performed a painless amputation of the leg while the patient was in the hypnotic slumber.

Many other attempts were made to perform operations painlessly during the hypnotic state, but they were seldom successful. In hysteria or other pathological conditions of the nervous system hypnotic anæsthesia is more easily brought about. It is well known that hypnotism has of late attained a growing importance for diagnostic purposes and as a therapeutic measure. It can at times be advantageously used on surgical patients.

Two Americans—the chemist Charles Jackson and the dentist W. L. G. Morton—introduced ether as an anæsthetic into general surgical use, after the inhalation of ether had already been used by others to allay pain and the physiological action of the vapour was known. Furthermore, in 1842 and 1843, W. C. Lang, a physician in Athens, had anæsthetised several patients with ether without publishing his observations. Morton induced Warren, the surgeon of the Massachusetts Hospital, to try the new remedy, and the latter, on October 17, 1846, removed without pain a tumour of the neck under ether narcosis. The knowledge of the new discovery spread quickly to Europe, first to England, then to France, Germany, and the other countries. In England, Robinson, Liston, and Simpson were the first to try it, and they were followed by Malgaigne in France. Schuh was the first in Germany, and on January 27, 1847, he removed, without pain, a telangeiectasis under ether.

But the supremacy of ether as an anæsthetic was not to continue long. In November, 1847, Simpson, as a result of some eighty observations, including surgical and labour cases, recommended chloroform, which had already been discovered in 1831 by Soubeiran, in Paris, and had lain unnoticed on the apothecary's shelves for sixteen years. Ether was very quickly superseded by chloroform, and the enthusiasm for the new remedy was tremendous. But soon the first deaths from chloroform were reported, and the wish for a new anæsthetic became active. Numerous other drugs were tried, but at the present day chloroform and ether hold the field in triumph without rivals worthy of the name. In recent times ether has again gained ground, and is

used especially in America, in Lyons, and lately also in England, in Switzerland, and in Germany. I use ether a great deal, particularly if the respiratory passages and the lungs are sound, and I am well satisfied with it. Both drugs, we shall see, have their advantages and disadvantages, and we can not get along without either of them. In my opinion ether should be used when the heart is diseased, and chloroform is preferable in cases with a pulmonary lesion. Ether is also to be preferred to chloroform in case of disease of the liver and kidney, as the latter is more likely to give rise to serious degeneration of these organs. Of the other anæsthetics, nitrous oxide, or laughing gas, and bromethyl are most used, chiefly for short operations and by dentists. We shall first take up chloroform.

§ 8. **Chloroform Narcosis.** *The Chemical Reactions of Chloroform.*—Trichlormethan ($CHCl_3$) is a clear, colourless, very volatile liquid, with a pleasant, aromatic odour, and a sweet and afterwards burning taste. It can be mixed with ether and alcohol in all proportions, and is soluble in two hundred parts of water. Chloroform is very slightly inflammable, and has at 15° C. (55° F.) a specific gravity of 1.502. It is decomposed by daylight into hydrochloric acid, chlorine, and free formic acid, and is therefore to be kept in the dark, preferably in glass bottles which are covered with pasteboard. By the addition of one half to one per cent. absolute alcohol the decomposition of chloroform can be prevented.

Only such chloroform should be used as has been previously proved to be pure. The impurities of chloroform consist in adulterations with spirits of wine, ether, etc., in the very dangerous compounds of methyl formed during its preparation, and finally in the decomposition products which develop if the drug is long exposed to the action of light and air (free chlorine, compounds of the hydrocarbons with chlorine, aldehyde, hydrochloric acid, acetic acid, and formic acid). The testing of chloroform is a chemical procedure, which must be done by the chemist or the apothecary; but the surgeon should always make Hepp's smelling test, which is as simple as it is useful. Chemically pure Swedish filter paper is dipped in chloroform, the latter allowed to evaporate, and the dry paper smelled of. If the chloroform is pure the paper has no odour; but if there is a peculiarly sharp and irritating odour the chloroform is impure, and it is either acid from decomposition or it contains the chlorine substitution products of the ethyl or methyl series. Chloroform can also be tested chemically by distillation over crude potash at a temperature of 60° to 61° C. (140° to 142° F.). The chloroform prepared from salicylide chloroform (Anschütz) is a perfectly pure form and can be recommended very heartily. The production of anæsthesia requires a somewhat longer time than in the case of the ordinary chloroform (usually from ten to twenty minutes), but the patient takes it well and unpleasant sequelæ are very rare. Chloroform medicans (Pictet), purified by crystallization, is also an excellent preparation.

Physiological Action of Chloroform.—By inhalation, chloroform vapour is carried to the lungs, or more particularly to the blood, and probably circu-

lates in the blood in chemical combination with the hæmoglobin of the red blood-corpuscles. Chloroform has the power in part of directly destroying the red blood-corpuscles, and in part of robbing them of their ability to take up oxygen and to drive out carbonic acid (Böttcher, Schmiedeberg, and others). The icterus—i. e., hæmatogenous icterus—which Nothnagel observed in animals is probably due to the power possessed by chloroform and ether of destroying the red blood-corpuscles.

The destruction of the red blood-corpuscles is preceded by a change in their form. They become spherical, and these spheres partially dissolve in the blood plasma, leaving behind small granules. Chloroform also combines intimately with the fixed tissue cells. It can therefore remain in the body for a longer or shorter time, depending upon the closeness of its combination with the cells. The blood is only the means, probably, of carrying the chloroform, and the chief cause of the anæsthesia is to be sought in the certain but not yet fully understood changes in the central nervous system. It is certain, however, that these changes do not depend upon disturbances of the circulation, such as hyperæmia or anæmia of the nerve centres. According to Luther, the physiological aud pathological action of chloroform depend chiefly upon its power of dissolving lecithin and cholesterin; the fatty degeneration produced in the kidney, liver, heart, muscles, etc., is to be regarded as a coagulation necrosis, and chemically as a lecithin degeneration of the cell protoplasm.

The drug is carried to all the organs by the blood as it circulates, including the central nervous system, the brain, and the spinal cord. The ganglion cells are chiefly affected, while the nerve fibres suffer no loss of function, but retain their normal excitability (Bernstein). The sensory ganglion cells are first attacked by the poison, then the motor, as is evident from the final paralysis of the automatic movements of the heart and respiration in a fatally ending narcosis. According to Flourens, the paralysis of the nerve centres begins in the great lobes of the brain; it then attacks the cerebellum, and finally the spinal cord, where first sensation and then motion are lost. The medulla oblongata retains its function the longest, then it also loses its activity, and life comes to an end. The loss of sensation and of the sense of pain is first noticeable in the back and extremities, and last in the cornea with its rich nerve supply.

The changes in the blood pressure and the action of the heart have been carefully studied by Lenz, Scheinesson, Koch, Bowditch, Minot, and others. Chloroform acts upon the vaso-motor centre, and also, in all probability, directly upon the heart muscle and its ganglia. The arterial tension is reduced, the blood pressure sinks, the energy of the heart's action is diminished, and the rapidity of the circulation is lessened. The blood of the whole body becomes more or less venous, and a decrease in oxidation with a sinking of the temperature of the body takes place as a result of the diminished heat production.

Respiration is influenced in two ways by chloroform: in the first place, the direct action of the chloroform upon the terminal branches of the fifth nerve in the mucous membrane of the nose may cause a temporary reflex cessation of breathing, and a noticeable slowing of the heart (stimulation of the vagus), particularly at the outset of the narcosis. In the second place,

chloroform acts directly upon the respiratory centre, and the changes thus brought about in respiration are independent of the changes in the circulation. The centre for breathing is first stimulated by chloroform, and later depressed, causing the breathing to become slower and more shallow.

The behaviour of the pupils is of very great importance. The dilatation of the pupils occurring at the outset of the narcosis is dependent upon the mental excitement of the patient and upon the reflex stimulation of the fibres of the sympathetic nerve governing the opening of the iris, brought about by the irritation of the branches of the trigeminal nerve in the naso-lachrymal duct. All these irritations which dilate the pupil cease when sleep or narcosis takes place, and the pupil is therefore contracted.

The uterine contractions during childbirth are not stopped during chloroform narcosis. The influence of the drug upon the muscular fibres of the intestine is not known. Chloroform produces a complete relaxation of the voluntary muscles. It is important to remember that chloroform is excreted in the milk of nursing women, and may be found in the blood of the fœtus.

Chloroform is excreted, according to Zeller, chiefly in the form of chlorides in the urine, and only about a third is excreted as unchanged chloroform by the lungs and kidneys. The excretion of the chlorine derived from the breaking up of the chloroform in the system is just as slow as the excretion of iodine after the external application of iodoform.

Unchanged chloroform can be found in the urine of a patient who has been chloroformed, and if the urine is boiled with Fehling's solution the latter will be immediately reduced to the black copper oxide, and not the red (Hegar-Kaltenbach, C. Theim, P. Fischer). As a result of the destruction of the red blood-cells by the action of chloroform, hæmoglobinuria occasionally occurs, though bilirubinuria is more common, for the reason that, owing to the destruction of the red blood-cells, an increased formation of bile colouring matter takes place, which is excreted in the urine. Nothnagel found biliary pigment in the urine of animals, while in man jaundice and bile pigment in the urine are rarer. The urine sometimes contains casts and albumen, more rarely sugar. Some authorities, including Fränkel, Wunderlich, and Ziegler, claim that transient albuminuria with casts is more common after the use of chloroform than of ether. A transient albuminuria occurs, according to Ajello, in eighty per cent., and according to Zachrisson in 38.06 to 44.45 per cent. of the cases of chloroform anæsthesia; while in the mixed chloroform-ether anæsthesia the percentage is 16.59 to 20.77. Rindskopf found that among ninety-three cases where chloroform had been used thirty-one showed pathological elements in the urine (albumen, casts, leucocytes, epithelium from different sources, and erythrocytes). The urine is usually normal again at the end of two or three days, but the experiments of Babacci and Bebi show that the nephritis resulting from chloroform is more likely to take on a chronic character than the nephritis following the use of ether. Thomson and Kemp, on the other hand, claim that ether is more harmful to the kidneys than chloroform. Nachod found in the urine of children, acetone and diacetic acid, both separately and in combination with one another. Kast and Mester found in the urine of patients who had died from the effects of a long-continued anæsthesia, a substance containing sulphur and resembling cystin. It follows from what has been said that the kidneys are more

or less damaged by the use of chloroform and that consequently it should be employed with caution. A patient should, for example, never be chloroformed a number of times within a few days.

§ 9. **Method of Administering Chloroform.**—If it has been decided to narcotise a patient for an operation, certain precautionary measures are to be observed. His general condition must be determined by a careful examination of the internal organs, especially the heart and lungs. In cases of extensive pulmonary disease, of pleurisy with effusion, of heart disease, particularly valvular insufficiency and fatty heart, of atheromatous degeneration of the arteries, of alcoholism, of great weakness from loss of blood, of nephritis, diabetes, epilepsy, many diseases of the brain, etc., one must be very careful in the use of anæsthetics, and one must decide in each case whether the narcosis is justifiable. In diseases of the heart ether should always be used in preference to chloroform.

If possible, the patient's stomach should be empty, since otherwise the vomiting, which so easily occurs, will disturb the quiet progress of the narcosis and of the operation; moreover, the movements of the diaphragm during the narcosis are interfered with when the stomach is distended. Therefore, without exception, patients should be forbidden to take solid food for from three to four hours before the operation. In England and America it is customary to give stimulants, especially to weak patients, before the narcosis. Poncel gives repeated hypodermic injections before, during, and after chloroform anæsthesia of four cubic centimetres of diluted cognac at a temperature of 38° C. (one part cognac to two parts water). The administration of alcohol in some form by mouth before beginning the anæsthetic is simpler, and is particularly desirable in the case of alcoholic patients. For a description of morphine-chloroform anæsthesia and oxysparteine-morphine-chloroform anæsthesia, the reader is referred to page 46. I shall merely mention here that I always inject morphine ten to twenty minutes before beginning the chloroform or ether in adults. In many operations, particularly those in the peritoneal cavity and about the region of the anus, etc., the intestine should be previously emptied by a laxative or enema.

The patient should be clothed as lightly as possible, with no constriction in the region of the neck, thorax, or abdomen which interferes with respiration, and the thorax should be uncovered so that the respiratory movements can be watched. Care must be taken not to allow the patient to become chilled, as marked lowering of the blood pressure with fatal collapse may result. For the same reason, the operating room must be kept moderately warm. Too high a temperature in the

room is to be avoided, as it likewise causes a lowering of the blood pressure (Allen). In suitable cases, operating tables that can be heated are used (see page 7). False teeth and plates must be removed from the mouth. In order to diminish the dangerous reflex action of the heart, produced through the branches of the trigeminal nerve within the nose, Guérin has advised that the nostrils be closed with cotton, some form of clamp, or the fingers, so that the patient breathes only through the mouth. To accomplish the same purpose, Rosenberg recommends cocainisation of the interior of the nose by means of a spray. He uses 0.02 of a ten-per-cent. solution, and three minutes later 0.01 in each nostril. If the anæsthesia has to be much prolonged he repeats the cocainisation every half hour. Gerster tested this procedure in one hundred cases, and found it efficient except in alcoholic patients. During the stage of excitement, in the first part of the narcosis, I fasten the patient to the operating table by means of a leather strap passed over the thighs. The horizontal position is usually employed, with the head slightly raised.

In giving ether, the patient's head should be inclined somewhat backward or downward, to prevent the mucus that collects in the mouth and throat from being aspirated into the lungs, causing pneumonia. In operations on the face, in the mouth, throat, or nose, the blood is prevented from entering the trachea by using the morphine-chloroform anæsthesia (see page 45, Mixed Narcosis), or by operating with the patient sitting up with the head held forward, or lying down with the head hanging back over the edge of the table. In operating on the patient in a sitting posture, one must guard against fatal syncope from cerebral anæmia.

If the operation must be performed with the patient lying upon his abdomen or side, it will be necessary to watch the respiration and heart action with great care. In order to have good control over the narcosis, and in case of accidents, one should never administer chloroform without the presence of an assistant; in case death should occur from chloroform, as well as for other reasons, it is well to have a witness present.

When the narcosis is to begin the patient should be quieted by a few words. It is important that the patient's surroundings should be quiet, and any excitement on his part is to be avoided. For this reason he should be spared as far as possible the shock of seeing the instruments and other preparations for the operation. While inhaling the chloroform he should be made to count out loud slowly, in order that the breathing may be regular and the gradual effect of the chloroform may be watched.

Chloroform may be administered in case of emergency by pouring it upon a sponge or a folded cloth placed over the face. It is better, however, to use a special mask, such as the one shown in Fig. 19. This consists of a wire frame covered with porous woollen cloth or thin flannel.

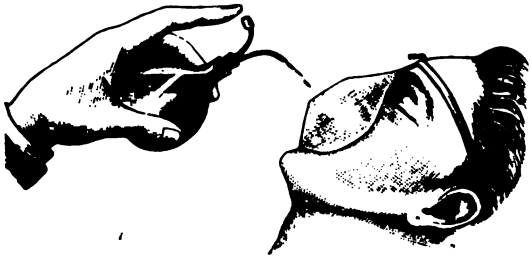


Fig. 19.—Esmarch method of administering chloroform.

Lately I have been using the excellent chloroform mask which I saw used in Kocher's clinic. The wire frame, which is easily sterilised, is made of two pieces, *A* and *B* (Fig. 20), which fold together on a hinge, inclosing between them a piece of compress which has been previously spread out on the frame *A*. Rosenberg has devised a chloroform mask with a graduated bottle attached. Masks made of glass, which allow the anæsthetist to watch the patient's face, have also been employed.

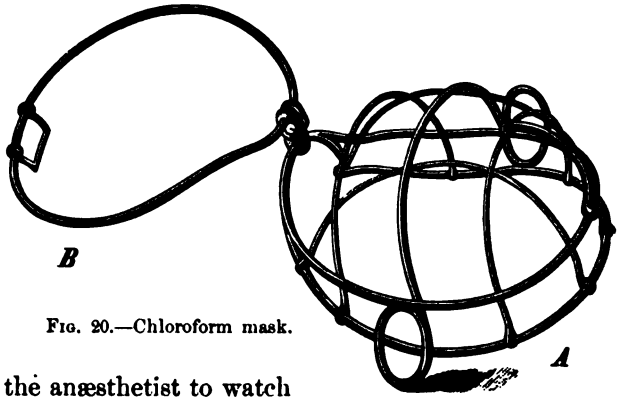


Fig. 20.—Chloroform mask.

In administering chloroform, care must be taken not to allow the patient to inhale the vapour in too concentrated a form, but to permit a suitable admixture with atmospheric air. For this reason the chloroform should not be poured on the mask too abundantly, and the mask should not be pressed down too tightly over the face. It should be administered in drops, but

Fig. 21.—Chloroform mask.

continuously. For this purpose the dropper shown in Fig. 22 may be attached to any bottle. If the chloroform is poured out too freely it not infrequently runs on to the neck and chest, and can cause a very troublesome erythema or burn. So it is best to lay a light compress on the neck of the patient, and to place a piece of cotton or a small sponge on the inner surface of the cloth which covers the apparatus.

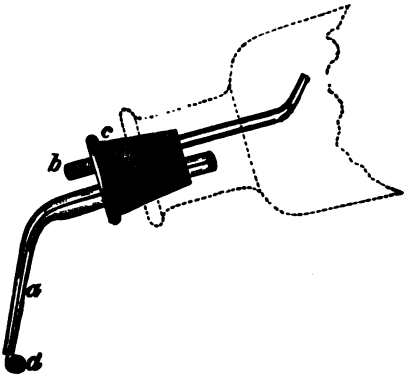


Fig. 22.—Chloroform-dropper consisting of the capillary tube *a*, with silver wire *d*, the small tube *b* admitting air, and the cork, *c*.

Several forms of apparatus have been devised for mixing the chloroform vapour with a known proportion of air, a matter which is of great importance (Bert, Kronecker, Péan, Thiriar, Kappeler). One of the best of these is Junker's (Fig. 23), the description of which is as follows:

The Chloroform Apparatus of Junker and Kappeler.—The flask *F* is filled to about one third with chloroform, and is fastened by a hook to a buttonhole on the chloroformer's coat. By pressing the rubber bulb *B* a mixture of chloroform and air is supplied to the patient. The mouthpiece which the patient wears is connected with the flask *F* by a rubber tube, and is made of hard rubber or nickel-plated metal, with incisures to fit the nose and chin, over each of which there is a valve to allow for expiration, and two other valves which can be closed or opened to admit air, thus permitting the chloroform-air mixture to be further diluted. Both of the latter valves are placed at the junction of the mouthpiece with the tube from the flask *F*. The expiratory valve is situated in the other and smaller of the attachments to the mouthpiece. Kappeler has lately modified the Junker apparatus so as to allow the chloroform to be mixed with air in a definite proportion. He recommends the proportion of 10.17 grammes of chloroform to 100 litres of air (see page 36). Wiskemann's apparatus likewise makes it possible to administer chloroform in a definite amount and proportion.

Fig. 23.—Junker's apparatus for administering chloroform.

Suitable instruments should be ready, in case at any time during the narcosis it may be necessary to forcibly open the mouth and pull forward the tongue, which may have fallen back and plugged the pharynx. A wedge-shaped piece of wood is the simplest instrument for forcibly opening the mouth, though Heister and Roser have devised special instruments for this purpose. Heister's is represented as open in Fig. 24. By turning the thumb-screw and separating the two bars which lie in contact when the instrument is closed, the jaws are forced apart. Roser's mouth-gag is illustrated in Fig. 25 as it appears when

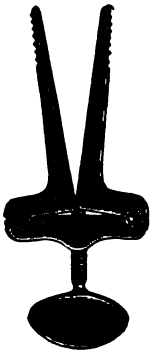


FIG. 24.—Heister's mouth speculum.

FIG. 25.—Roser's mouth-gag.

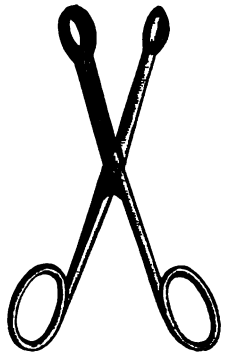


FIG. 26.—Forceps for drawing the tongue forward.

opened. In Fig. 26 is shown an excellent form of forceps for seizing and drawing out the tongue; one of these should be fastened in a buttonhole of the chloroformer's coat.

During the progress of the narcosis the condition of the pulse, respiration, pupils, and the colour of the face must all be carefully watched. It is important that the patient's arms and shoulders should be properly placed during anæsthetisation. Paralysis of the arm, chiefly in the distribution of the musculo-spiral, but also of the median and ulnar nerves, may result from forcible abduction or hyperextension of the arm, which causes the brachial plexus to be compressed between the clavicle and first rib or between the former and the transverse process of the sixth or seventh cervical vertebra. In rare cases—e. g., when the reflexes are increased—these paralyses have a central origin and are caused by the chloroform. The prognosis of these paralyses is, generally speaking, favourable, but recovery often requires a long time. The physician administering the anæsthetic should have nothing else to do, and should let nothing divert his attention from his duties.

Decomposition of Chloroform Vapour by the Flame of a Gas-light.—When the vapour of chloroform comes in contact with the flame of a gas-jet there are formed tetrachloride of carbon, hydrochloric-acid gas, and free chlorine (Bosshard), the latter being two gases which according to Stobwasser, when inhaled by rabbits and guinea-pigs, may cause death from œdema of the lungs and hæmorrhages into the lung substance. According to Kunkel, the hydrochloric acid is the chief cause of the discomfort experienced in using chloroform by candle and lamp light. He found chlorine only in small amounts, which were probably set free by the decomposition of hydrochloric acid.

Zweifel has observed bronchitis and pneumonia following the administration of chloroform by gas-light, on account of the decomposition of the chloroform; and he himself lost a patient from catarrhal pneumonia. The fumes are often so strong as to make everybody in the operating room cough. To overcome this difficulty, Kunkel recommends abundant ventilation, or, if this is not possible, as, for example, during a laparotomy, the use of a spray or saturation of cloths with water, milk of lime, soda, or borax, to absorb the hydrochloric acid. The best way of getting about the difficulty is to use Junker's apparatus or ether.

§ 10. **Symptomatology of Chloroform Narcosis.**—The symptoms of chloroform narcosis have been divided into separate stages, which, though not sharply defined from one another, are each very different. They are (1) the stage of volition, (2) the stage of excitement, and (3) the stage of tolerance. Kappeler speaks of two stages: one of consciousness, and the other of unconsciousness.

Sometimes, particularly in the case of weak and exhausted individuals, the chloroform sleep comes on without any intermediate stage, but as a rule it is preceded by a well-marked stage of excitement. The patient becomes restless, and begins to talk, cry out, shout, sing, laugh, weep, etc. Many patients fling their arms and legs about, try to get up, and act as though insane. Gradually the movements of the arms and legs cease; they become limp; the face, which has usually hitherto been purple, now becomes pale; the pupils are contracted, and no longer react to light or mechanical stimulation; the pulse becomes distinctly slower, the respiration quiet, regular, and at times rather shallow; the patient is completely insensible, and the operation can begin.

The skill of the chloroformer consists in keeping the patient in this stage of the narcosis throughout the operation, permitting him neither to awake nor to be overcome by a fatal paralysis of respiration or of the heart. The behaviour of the pupils, the pulse, and the respiration must be carefully watched.

When the anæsthesia is complete, the pupils, which so long as consciousness was not entirely lost began slowly to dilate, now become contracted. By touching the cornea their degree of dilatation will not be affected, since the cornea is without sensation. Sudden dilatation of

the pupils during the narcosis is a dangerous symptom, indicating a threatened fatal cardiac paralysis. At times, in deep chloroform narcosis, there occurs an asymmetrical movement of the eyeballs. In such cases, while one eye may remain looking steadily forward, the other may turn slowly inward, outward, or upward. In other cases both eyes may turn either in opposite directions or varying distances in the same direction. The occurrence of asymmetrical movements of the eyes is a sure indication of deep narcosis; the co-ordination of the ocular movements returns when the patient awakes.

The heart's action is increased at the beginning of the chloroform narcosis, and the pulse becomes more rapid; but with the loss of sensibility coincident with contraction of the pupils and the paralysis of the voluntary muscles, the heart's action becomes weaker and the frequency of the pulse falls below the normal. Kappeler found that the frequency of the pulse, a few hours before narcosis, differed by from four to thirty beats, as compared with that during the narcosis.

The pulse curves obtained by the sphygmograph teach that chloroform lowers the arterial pressure, and this is of great importance for the explanation of the deaths from chloroform. Ether has the opposite effect—it raises the blood pressure and the pulse becomes stronger. Hand in hand with the slowing of the circulation and the diminution of the blood pressure there is a loss of body temperature, which, according to the measurements of Kappeler, amounts to between 0.2° to 1.1° C., or an average of 0.59° C.

The behaviour of respiration varies greatly with the individual, but both the frequency and the depth of the breathing diminish as the administration of the chloroform is prolonged. Chloroform acts locally upon the nerves of the respiratory tract, as well as on the respiratory centre. In any stage of chloroform narcosis, particularly in the first, there may be a cessation of respiration, or its normal course can be seriously interfered with by the tongue falling back against the posterior wall of the pharynx. Retching or vomiting is of frequent occurrence during all stages of chloroform narcosis, but particularly in the first, if the patient has had something to eat a short time previously.

Loss of sensation occurs first in the back and extremities, later in the genitalia, then in the face and head, and finally in the cornea, with its abundant nerve supply, and after the termination of the narcosis sensation returns to these parts in the reverse order.

At the close of the operation the patient should be carried as soon as possible into another well-aired and well-warmed room, and should be carefully watched until he has returned to complete consciousness. Elimination of the chloroform takes place more quickly in a warm than in a cold room.

The recovery from the narcosis occurs rather quickly, with a sudden dilatation of the pupils.

Many patients after awakening act as though drunk. Women, in particular, are apt to be excited, and weep, or perhaps have serious fits of hiccoughing and hysterical crying. Others, particularly children, after awakening fall asleep again, while still others cause anxiety by remaining asleep for a long time.

To prevent vomiting, which very often occurs after anæsthetisation, the patient should get very little to drink. For the severe thirst frequent rinsing of the mouth with cold water is very serviceable. Not infrequently the vomiting is severe during the first twelve to twenty-four or even forty-eight hours after the narcosis. In such obstinate cases an ice-bag should be laid on the back of the neck and over the stomach, and strong black coffee, or iced champagne, or small pieces of ice may be given at intervals by mouth, and as a last resort a subcutaneous injection of morphine may be administered in the region of the stomach. Neuber uses a subcutaneous injection of caffeine two or three times a day (0.03 caffeine in a solution of 1.0 caffeine with 12.5 each of distilled water and alcohol). Too much water and ice increase the vomiting, and so should be avoided.

§ 11. **Accidents Occurring during Chloroform Narcosis.**—1. *Vomiting.*—Retching or actual vomiting may occur at any stage, but especially before the complete loss of consciousness and toward the close of the narcosis. If the stomach is full, vomiting regularly takes place. Occasionally death has been caused by asphyxia, due to the inhalation of stomach contents. During the act of vomiting the patient usually recovers consciousness, thus causing the narcosis and the operation to be prolonged. When vomiting occurs the head of the patient should be turned to one side, and if the mouth is tightly closed it must be opened by force with one of the instruments illustrated on page 26.

2. *Anomalies of Respiration.*—Irregular respiratory movements are generally—in fact almost always—to be expected during the narcosis.

In the beginning of the latter there is not infrequently a cessation of respiration in expiration, generally accompanied by a spasmodic closure of the glottis. As has been mentioned on page 28, this temporary apnœa is caused reflexly by the chloroform vapour coming in contact with the end filaments of the fifth nerve in the nasal mucous membrane. But the danger is greater if respiration stops during the stage of excitement, giving the characteristic picture of asphyxiation: the thorax is as stiff as a board, the jaws are tightly closed, the tongue is drawn back against the posterior pharyngeal wall, pressing down

the epiglottis, and so closing the larynx, while the face becomes bluish red. Under these circumstances death can result; but such a picture should cause no alarm in one who is experienced, as this disturbance in the respiration can be easily remedied. After the stage of excitement has passed, and the patient is fully under the influence of chloroform, respiration can be easily interrupted by the tongue falling backward of its own weight, pushing down the epiglottis, and thus closing the entrance into the larynx. The bluish-red colouration of the face in such cases calls attention to an interruption in the respiration. In other cases the disturbances of respiration are caused by paralysis of the respiratory centre, due to the action of the chloroform vapour.

Linhart saw a singular cause for the asphyxia in a girl who had a very pointed nose and extremely thin alæ nasi. The latter were pressed tightly against the septum on both sides by atmospheric pressure during inspiration and thus closed the anterior nares, and at the same time the mouth could not be opened, owing to trismus. The alæ were pried apart with a penknife and air rushed into the nose, making a distinctly audible noise. Other surgeons have observed the same phenomenon.

3. *Disturbances in the Circulation.*—These are extremely dangerous, and sometimes occur at the beginning of the narcosis, but more frequently after the administration of chloroform has been kept up some time; in other words, in the stage of tolerance or deep narcosis. No matter whether the respiration is normal or not, if the radial pulse becomes intermittent and the face pale there is need of the greatest care to prevent the threatened syncope from proving fatal. It occurs sometimes quite suddenly and without warning, and the impending danger is not foretold by irregularity of the pulse. In a case of chloroform syncope the face turns very suddenly waxy white and corpselike, the cornea becomes dull, the pupils are dilated to their fullest extent and do not react, the radial pulse can not be felt, the heart sounds are very faint or inaudible, blood ceases to flow from the divided arteries, or the blood that does flow out is in the form of a few dark drops, the muscles become flabby, and respiration ceases. This is the picture of cardiac paralysis. Energetic measures must be adopted at once, otherwise the patient is lost (see § 13).

§ 12. **The Occurrence and Causes of Death from Chloroform.**—The number of published deaths due to chloroform does not, of course, give any idea of their frequency. The fatal cases are much too often kept quiet.

Legal Responsibility of the Physician in Cases of Death during Narcosis.—Borntrager, E. Hankel, and Dumont have made noteworthy contributions to the subject of the legal responsibility of the physician

in the administration of chloroform and other anæsthetics; and Dumont maintains that the physician is answerable for a death when he administers ether to a patient with pulmonary disease, and chloroform to one with a cardiac lesion. I should not consider this assertion of much legal value, as a correct decision can only be reached after consideration of each case by itself.

Death from chloroform occurs in most cases suddenly during the administration of the same. Sometimes, however, it does not take place until one or more days afterwards, in spite of the fact that the patient has come out of its influence. This is likely to be the case when the narcosis has been prolonged, or has been repeated a number of times at short intervals. These cases are characterised by frequent and severe vomiting, high pulse rate, psychical disturbances, and symptoms of collapse, during which death takes place more or less suddenly.

Statistics of Death from Chloroform.—The statistics showing the frequency of death from chloroform vary very widely. Rendle (London) estimates the mortality of chloroform anæsthesia at 1 to 2,666, and Zachrisson at 1 to 3,045. Richards found the ratio for eight English hospitals from 1848 to 1864 to be 1 to 17,000, and from 1865 to 1869 1 to 1,250. There is a very noticeable difference in the statistics of the various hospitals.

In one hospital a long interval of time will pass with a great number of cases of chloroform narcosis without a single death, while in another, in the same time and with the same number of cases, there are several accidents. This variation in the proportion of chloroform deaths in this or that hospital can be partly explained by the greater or less skill of the one intrusted with the administration of the drug.

Rendle estimates the number of people chloroformed yearly, in the twenty hospitals in London, at 8,000, with about three deaths, or 1 in 2,666.

Billroth had his first fatal case after giving chloroform 12,500 times. Nussbaum gave it 15,000 times without a death.

The mortality statistics of the Deutsche Gesellschaft für Chirurgie showed in 1897 a total of 327,593 narcoses and 134 deaths—i. e., a ratio of 1 to 2,444. The mortality of the different anæsthetics used was as follows: Chloroform, 1 death in 2,039; ether, 1 in 5,090 (pneumonia resulted frequently—in 1895, out of 30 cases of pneumonia 15 died); Billroth's chloroform-ether-alcohol mixture (see page 46), 1 in 3,870; bromethyl, 1 in 5,228; ether and chloroform, 1 in 7,594; pental, 1 in 213. This anæsthetic is not found in the reports of the later years. It has probably been given up entirely.

The mortality from chloroform as well as from ether is higher than reported, as so many fatal cases are kept quiet. Though there are great differences in the statistical reports regarding the mortality of chloroform, one fact is certain—viz., that chloroform anæsthesia is not without danger, and hence should be employed only when absolutely necessary. When possible, local anæsthesia, which is practically without danger, should be substituted. According to the above statistics, the combined anæsthesia, with chloroform and ether, is the least dangerous.

To get a better knowledge of the causes of death from chloroform, Kappeler collected the records of one hundred and one cases, seventy-eight of which were men and twenty-two women; in one case the sex was not mentioned. Of these one hundred and one, forty-three died before the full effect of the chloroform was obtained, forty-seven in deep narcosis, and in eleven the particular stage of the narcosis is not mentioned. The amount of chloroform used is known in forty-six cases, and it was, as a general thing, small, averaging 11.1 grammes, the smallest amount being twenty drops, and the most thirty to sixty grammes. Very diverse methods of administering the chloroform were used, such as sprinkling it on simple pieces of cloth, cotton, or the regular apparatus of Skinner, Esmarch, and others. As to the age of the patients who were operated upon for different diseases, two died under five years of age, twelve between the ages of five and fifteen, nineteen between sixteen and thirty, twenty-one between thirty-one and forty-five, twenty-five between forty-six and sixty. Of those over sixty years of age one died. In twenty-one cases the age is not given.

Causes of Death from Chloroform.—The *causes of death* from chloroform are very varied, and frequently the chloroform is not to blame at all. If a patient chokes from aspirating vomitus into the trachea and bronchi, or from getting a set of false teeth into his larynx during the chloroform narcosis, this sort of death is plainly not due to the chloroform. A certain number of sudden deaths take place even before the administration of the chloroform has been begun. Desault, for instance, was about to perform a lithotomy, and, to demonstrate to the spectators his line of incision, drew his finger-nail over the patient's perinæum, whereupon the latter suddenly uttered a loud cry and died instantly. Cazenave was going to perform an amputation, but the patient was in such a state of nervous depression that he did not venture to give him chloroform, and only pretended to do so by holding a cloth, with nothing on it, over his face. Suddenly his respiration stopped, his heart ceased to beat, and the patient was dead. The first patient to whom Simpson attempted to administer chloroform died under similar circumstances. The attendant who was to bring the chloroform into the operating room stumbled, fell, and broke the bottle containing the drug, and spilled all the chloroform on the floor. The operation, which was for hernia (herniotomy), had to be performed without chloroform, and at the first incision through the skin the patient died. It is difficult to give a satisfactory explanation for these sudden deaths. They are probably the result of a syncope due to the intense nervous excitement. Sudden deaths during the administration of chloroform also occur in young individuals from twelve to thirty years of age with a lymphatic and chlorotic constitution (hyperplasia of the thymus, enlargement of the spleen and lymph glands, etc.—*status thymicus*). Furthermore, in cases which must be operated upon after having lost a great deal of blood, if death occurs from cardiac paralysis during the administration of the chloroform, it is not to be put down to the anæsthetic. We must separate all these cases of death occurring during the narcosis from the cases of death really caused by chloroform. In the latter, death is caused principally by paralysis of the heart (syncope) or paralysis of respiration (asphyxia). In cases of death from syncope, the heart's action ceases before or almost at the same time that respiration does; but

in cases of death from asphyxia the respiration ceases first, and the heart's action afterwards. In any case, whether the result of syncope or asphyxia, death can occur before or during the time that the full effect of chloroform is obtained, and therefore at the beginning or at any period of the narcosis proper.

Of the twenty-three cases of death from syncope which Kappeler collected, fourteen patients were completely and nine partially chloroformed. Death from asphyxia occurred ten times during complete and seven times during partial narcosis. If death occurs in the first part of true narcosis, and therefore before the full effect of chloroform has been obtained, the cessation of respiration, or the cessation of the heart's action, is in all probability dependent upon the trigeminus-vagus reflex, as mentioned on page 20. Death from asphyxia in the stage of incomplete narcosis may also be caused by spasmodic retraction of the tongue over the entrance of the larynx, or by spasm of the abdominal muscles or of the diaphragm. Death from chloroform in the stage of deep narcosis is caused by the direct paralysis of the circulatory and respiratory centres in the medulla oblongata; but death from asphyxia during this same stage can also occur if the tongue falls back ever the entrance into the larynx.

When death occurs with the patient fully under the influence of chloroform, it is usually the result of heart failure. The blood pressure falls because the heart action weakens, but not from paralysis of the vaso-motor centre. The latter seems to withstand the paralysing action of chloroform better than the nervous mechanism of the heart, particularly if it obtain sufficient oxygenated blood. The same seems to be true of the respiratory centre, and the peripheral nerves in the lungs (pneumogastric). If, however, the blood, in consequence of impaired breathing, is overloaded with carbonic acid, fatal paralysis of the vaso-motor and respiratory centres can more easily occur (Evans). The theory advanced by Robin and Chapman that chloroform kills by extracting oxygen from the blood, or preventing its being taken up by the blood, is, according to Knoll's experiments, no longer tenable. A fatal outcome is favoured by an impure preparation, by the use of too concentrated a mixture of air and chloroform, by individual peculiarities of the patient, and by lack of skill on the part of the anæsthetist, consisting particularly in failure to watch the pulse and respiration.

How far impure chloroform is responsible for death in this or that case is difficult to say. Dangerous methyl compounds (see page 19) are to be feared.

It has been proved by numerous experiments that it is particularly dangerous to inhale chloroform vapour in too concentrated a form, and Snow, Sanson, and the English committee which investigated the cases of death from chloroform published an urgent warning on this point. Lallemand, Perkin, and Duroy showed that mammals will quickly die if they are made to breathe a mixture consisting of 8 parts of chloroform to 100 of air, while they can safely breathe a four-per-cent. mixture. According to Snow, 5 parts of chloroform to 95 parts of air can be safely inhaled, but mammals will die if the mixture is made eight or ten per cent. by volume. According to the English Chloroform Committee, the drug should only be inhaled in the strength of three and a half to four and a half per cent.,

and never in the form of concentrated vapour, the latter being the chief cause of the sudden reflex stoppage of respiration and slowing of the heart from stimulation of the filaments of the trigeminal nerve in the nose and throat.

Bert came to the same conclusions in his experiments on dogs. According to him there are two limits for the action of chloroform, one for anæsthesia (10 parts of chloroform to 100 of air), and one for immediate death (20 to 100). The best plan is to use a strong dose of chloroform to produce immediate anæsthesia, and then to continue the anæsthesia with weak mixtures of air and chloroform. Generally speaking, the proper mixture is 8 grammes of chloroform to 100 litres of air. The experiments conducted by Bert show that we use our anæsthetics in much too large amounts, and in too great concentration.

The Influence of Pathological Conditions upon Death from Chloroform.—What pathological conditions favour the occurrence of death from chloroform, and what does the post-mortem examination teach on this subject? In the first place it should be emphasised that many individuals without demonstrable pathological lesions are markedly susceptible to the injurious effects of chloroform. Young scrofulous and anæmic persons under thirty years of age, with hypertrophy of the thymus and the thyroid gland (*status thymicus*, Paltauf) belong to this class.

In general there may be mentioned, as dangerous complications of chloroform narcosis, fatty degeneration of the muscles of the heart, valvular lesions, atheromatous degeneration of the walls of the vessels, particularly of the coronary arteries, anæmia, chiefly as a result of excessive loss of blood, chronic pulmonary disease, such as emphysema, diseases of the kidney (morbus Brightii), and chronic alcoholism. In all such cases the narcosis must be conducted with the greatest caution. Fatty degeneration of the muscles of the heart is particularly dangerous. Sanson found fatty heart in eighteen out of fifty-six cases of death from chloroform, and Kappeler's statistics show it sixteen times in sixty cases.

Nothnagel, Ungar, Strassman, and Ostertag have shown that dogs kept for hours, during several days in succession, under the influence of chloroform, die from extensive fatty degeneration, the autopsy showing fatty degeneration of the heart, liver, kidneys, voluntary muscles, stomach, and mucous membranes. Drunkards, as a general thing, bear the narcosis badly, and it is characteristic for them to show marked disturbances of the nervous and muscular systems, with threatened cessation of respiration, and with great tendency to collapse. Diabetics are also not good subjects for chloroform or ether. They die not infrequently two or three days afterwards in coma. According to Becker, the acetonuria (a sign of increased amount of albumen) which is present plays an important part in the fatal outcome of this diabetic coma following anæsthesia. The severer forms of acute or chronic anæmia increase the chances of death from syncope, and it is well known that the activity of the central nervous system depends upon the amount of blood circulating through it, and the proportion of oxygen which it contains. If two animals of the same size are taken, and the same amount of chloroform is given to each, and venesection is performed upon one, the latter will die before the other.

Chloroform Poisoning.—Acute chloroform poisoning, which results from drinking large amounts of chloroform, has been observed, particularly in small children, but the children generally recover with proper treatment—artificial respiration, washing out the stomach, etc.

The Results of Autopsy in Cases of Death from Chloroform.—The autopsy in cases of death from chloroform generally reveals little that is characteristic, and often gives no satisfactory explanation of the cause of death. Not infrequently, however, the above-mentioned changes in the viscera are present, and after protracted anæsthesia, as well as in the cases that die from collapse three or four days later, there are found fatty degeneration of the heart, blood-vessels, liver, kidneys, and striated muscles. According to Luther, these degenerative changes in the cells of the various organs are conditioned upon a lecithin degeneration of the cell protoplasm. He explains the fatal effect of the chloroform from this degeneration, and from the presence of the alkaloid cholin, which is derived from the lecithin. The blood is ordinarily uncoagulated and dark coloured, but microscopic or chemical examination of it has hitherto given no satisfactory explanation for death. It is worth noting, however, that, as a result of the disturbance of respiration, the blood is overloaded with carbonic acid. An observation made by Recklinghausen is interesting in this connection. In three cases he found bubbles of gas in the great venous trunks and in the heart, and in each instance death occurred very quickly after taking a very small amount of pure chloroform, the pulse stopping suddenly, while shallow breathing continued for a short time afterwards. It could not be determined what the bubbles of gas were, and Sonnenberg was unable to elucidate this point by experiments upon animals. The experiments only showed that nitrogen under certain circumstances is set free within the blood-vessels. Before the above observation was made, Langenbeck and Pirogoff had also noticed considerable amounts of gas in the large venous trunks and in the right ventricle of the heart in cases of death from chloroform. Kappeler's more recent researches have shown that this evolution of gas is not peculiar to the death from chloroform, but is due to post-mortem changes. If the gas is set free to any extent during life, or if its presence was caused by venesection, death is produced by mechanical interference with the heart's action, as happened, for example, in Pirogoff's case. Mention should be made of the fact that Winogradow found granular degeneration of the ganglia of the heart and of the nerve cells of the brain and the spinal cord in both men and animals after death from chloroform.

Narcosis with a Mixture of Chloroform and Oxygen.—J. Neudörfer tries to explain the common accidents and fatal results from chloroform narcosis in the following way: The affinity of hæmoglobin for oxygen is not constant, and varies with the condition of health, being now less, now greater, according to the general vitality of the individual; and so, according to Neudörfer, when this affinity is weak the hæmoglobin's power of absorbing oxygen is more influenced not only by the oxides of carbon and nitrogen, but also by other gases and vapours, by temperature, and by atmospheric pressure, than when the affinity is stronger. In case of a weak affinity it is possible that the hæmoglobin may take up little or no oxygen, and that hence the chloroform may exercise its poisonous action. Neudörfer recommends a three- to

ten-per-cent. mixture of chloroform and oxygen as the least dangerous way of administering the drug.

§ 13. **Treatment of Common Accidents Occurring during Chloroform Narcosis.**—The common accidents that may occur during chloroform anæsthesia are: (1) Vomiting; (2) disturbances of the respiration and heart's action. In every case the chloroform should be stopped at once. If the patient vomits, his head should be turned to one side, the mouth is quickly opened by means of one of the gags shown in Figs. 24 and 25, and the vomited material is removed by wiping out the mouth. The chief anxiety consists in overcoming the impediments to respiration, and restoring the heart's action.

Overcoming Mechanical Interference with Respiration.—The impediment to respiration may, in the first place, be caused by the occlusion of the opening into the larynx by the tongue. In order to free the air-passage in such a case we have three means: (1) Push forward and raise the lower jaw; (2) draw out the tongue; (3) elevate the thorax and let the head and neck fall back (Howard).

Fig. 27.—The manner of pushing forward the lower jaw for threatened asphyxia.

To draw forward and lift up the lower jaw, seize the latter behind the angle and push it forward and upwards (Fig. 27). By this procedure the tongue and hyoid bone are drawn forward, rendering the hyo-epiglottic ligament tense, and this immediately lifts the epiglottis and opens the entrance to the larynx. The tongue forceps illustrated in Fig. 26 is another means of effecting the same result; or a loop of thread may be similarly used, or a pointed hook may be passed behind the middle of the body of the hyoid bone to draw it forward (Braune). Another good plan is to pass the forefinger down to the epiglottis, and by raising it open the larynx.

By Howard's plan of extending the head and neck backwards, the point of support of the tongue, which had fallen back when the patient was in the horizontal position, is changed from the posterior wall of the pharynx to the hard palate or the boundary between the hard and soft palates, thus making free for the stream of air the space between the root of the tongue and the posterior pharyngeal wall.

Artificial Respiration.—If these measures are not enough to restore the interrupted breathing, artificial respiration must be begun immediately. It is absolutely essential in performing artificial respiration that the air really obtains a free entrance to the lungs. Hence the

tongue should be drawn well out of the mouth; fluids or foreign bodies should be removed by lowering the head, or by placing the patient on his abdomen, supporting the epigastrium and forcibly compressing the latter, or finally by aspiration with a rubber catheter. Tracheotomy may be necessary. Every second increases the danger of the threatened death, particularly if the pulse is irregular and if the face becomes deadly pale or bluish. Artificial respiration is performed with the patient in the position indicated in Fig. 28. The operator grasps the lower portion of the thorax and makes vigorous rhythmical expiratory movements by pressing together the lower lateral portions of the thorax. At the same time the lower jaw is elevated and the tongue drawn forward. Laborde recommends rhythmical traction on the tongue by grasping its posterior portion (fifteen to twenty times a minute). This is supposed to stimulate the respiratory centre indirectly through the laryngeal nerve.

Fig. 28.—Artificial respiration.

Fig. 29.

Fig. 30.

Figs. 29 and 30.—Artificial respiration (Silvester).

Silvester's method for performing artificial respiration is better (Figs. 29, 30). The patient is placed as quickly as possible in the horizontal position, or with the head directed downwards; the operator stands behind the patient, and, grasping the arms, flexed at the elbow, presses them laterally against the chest and then draws the arms back-

wards till they are stretched out horizontally above the head. In this procedure the ribs are raised by the traction of the pectoral muscles.

Schüller has recommended grasping the arch of the ribs on both sides, and, after vigorously raising them, pressing them down against the thoracic cavity. The experiments and manometric measurements made by Djelitzin show that the Silvester and Schüller methods of producing artificial respiration are the best. Artificial respiration should be combined with vigorous blows over the region of the heart, which stimulate its action. Kraske has shown that, even after the heart has stopped beating, a kind of circulation can be kept up for a certain length of time by artificial respiration and by compression of the heart while the head is kept lowered. The deep inspiratory movements aspirate the venous blood into the right auricle.

Electrical stimulation of the phrenic nerves is another method of resuscitation (Duchenne). The electrodes of an induction apparatus are moistened and placed on either side of the neck, at the outer border of the sternomastoid muscle, which is pressed somewhat towards the median line, and near the lower end of the scalenus anticus. This stimulates not only the phrenic nerves, with the muscle they supply (the diaphragm), but also other nerves and muscles of inspiration (scalenus anticus, sternomastoid, pectorales, serrati, etc.). The stimulation should be interrupted about every two seconds, and expiration should be aided by compressing the thoracic and upper abdominal walls.

The insufflation of air by means of a catheter introduced into the larynx is not to be recommended. It may be necessary to perform a rapid tracheotomy and then do artificial respiration or insufflate air.

In desperate cases artificial respiration should be kept up from half an hour to an hour, or even longer. Life has been known to be restored after working twenty minutes, even when any measure seemed at first hopeless. There are successful cases on record in which artificial respiration was performed for three to four hours on people who were apparently drowned. Artificial respiration is also the best and surest way of restoring the action of a heart which is failing or has become imperceptible. The direct mechanical effect of compression and movement of the thoracic organs seems to have a stimulating power over the heart's action. The inversion or lowering of the head, accompanied by artificial respiration (Nélaton, Richardson, and others), appears to be particularly advantageous in cases of syncope from chloroform.

Electro-puncture of the Heart.—It has been recommended to stimulate the heart by introducing into its substance a needle charged with an electric current (acupuncture or electro-puncture); but this need only be mentioned

to be condemned as too dangerous. Sigmund Mayer has shown that this direct electrical stimulation of the heart by an interrupted or constant current acts as a heart poison. Watson experimented on animals, and found the heart could be punctured without danger, but if the vena cava was entered it was followed by a profuse hæmorrhage into the thoracic cavity. The right ventricle was entered thirty-eight times, the left six times; the right auricle was entered six times, the vena cava superior three times, the vena cava inferior twice, and the apex twice.

Of the other means which are recommended as restoratives to be used in addition to artificial respiration, if the breathing or heart action stop, I shall mention the following: Sprinkling the face with cold water; slapping the cheeks, forehead, or breast with the hand or with a wet towel; methodical rubbing of the extremities so as to assist the peripheral circulation and stimulate the cutaneous nerves; autotransfusion (see page 57); and the subcutaneous injection of a sodium chloride solution. W. Koch recommends placing the uncovered pole of the induction apparatus, or the copper wire itself, deep in the nasal cavity, and permitting a strong current to act directly on the nasal mucous membrane for ten to twenty seconds. After a single or repeated stimulation there usually occurs a deep inspiration or expiration, and breathing proceeds without assistance.

Should the respiration begin again, and the pulse become regular, suitable stimulants should be administered—olfactory stimulants, stimulating enemas of vinegar, wine mixed with water, or wine alone, subcutaneous injections of camphor or ether, etc.

As a prophylactic measure, particularly in the case of very weak, frightened, or excited individuals, it is wise to administer some alcoholic stimulant before the operation, such as Bordeaux or Marsala wine, and cognac to individuals accustomed to the use of alcohol.

The other Compounds of Methyl.—The other compounds of methyl—methyl ether, methylene bichloride, methylene ether, and methylal—are now but little used in surgery as anæsthetics. Methylene bichloride alone has found some warm adherents in Spencer Wells, Marshall, Gamgee, and other English surgeons. The drug possesses no real advantage over chloroform, and only seems to be less liable to cause vomiting. Its disadvantages are its inflammability and expensiveness. Furthermore, its use is not free from danger—in fact, it is probably more dangerous than chloroform. Kappeler mentions nine fatal cases. Methylene bichloride is best administered by Junker's apparatus, which is illustrated on page 25.

§ 14. **Ether Narcosis.**—Ether is another much-used anæsthetic which is coming to be employed more and more in the place of chloroform or its compounds. In America, ether narcosis is used almost exclusively, and in England, France, Switzerland, and even Germany, this drug is coming into constantly growing favour. I am very much pleased with ether as an anæsthetic, having used it in about three thousand cases without any serious after effects.

Ether—sulphuric ether, naphtha, ethylether, $C_4H_{10}O$—is a colou easily diffusible liquid possessing a pleasant odour and burning taste. is very volatile and inflammable, and boils at a temperature of 38° C specific gravity at 15° C. is 0.720. Ether that is to be used for anæst must be protected from light and air, and the bottles containing it shou kept filled. Its purity can be tested in the following way: Twenty centimetres are allowed to evaporate in a shallow glass. The moist left behind must be odorless, and should turn blue litmus paper neith nor white. If a few drops of a ten-per-cent. solution of ferrosulphat covered with ether in a watch glass, and a few drops of caustic sod added, the fluid should not turn brown inside of a minute.

The physiological action of ether is essentially the same as that of roform, except that ether seldom causes disturbances of the circulation hence does not so frequently kill by sudden paralysis of the heart. I and Holz showed by means of the tachometer that inhalations of ether an increase in the strength of the pulse, while chloroform, on the other weakens it. Angelesco and others claim that ether, by producing dilat of the vessels, lowers the body temperature more than chloroform, v causes a contraction of the vessels. Ether has no injurious effect upo blood either by lowering the percentage of hæmoglobin or destroyin red blood-corpuscles. The number of white corpuscles is increased, an leucocytosis reaches its maximum some hours after the narcosis (Le The mucous membranes are irritated by ether, and their secretion increased. Most of the statistics regarding the mortality of ether and cl form show that ether is less dangerous than chloroform. Among forty sand etherisations at the Hôtel-Dieu in Lyons, there was not a single case. Poppert is the only one who has claimed a high mortality for He included the cases that died some time later, particularly from pneum twenty-four to thirty-two hours after the operation. He found that was one death to every 1,167 etherisations, and for chloroform one de 2,647. It should be said, in reply to this, that all anæsthetics would a much higher mortality if we considered the cases that died twenty to thirty-six hours after the operation, and it is often difficult to say much the anæsthesia is responsible for the later deaths. Furthermor pneumonias that follow the use of ether can be easily prevented i anæsthetic is administered properly, and hence the drug should not be responsible when the fault lies in the way it is given. In my opinio present statistics do not give us any reliable data regarding the danger the use of ether and chloroform. Both drugs have their dangers, and the cases are much more common than the statistics show, as they are so not reported. For the mortality of the different anæsthetics as shown b statistics of the Deutsche Gesellschaft für Chirurgie see page 31.

The typical mode of death from ether is primary arrest of respir and secondary paralysis of the heart. Ether gives rise more frequently chloroform to later disturbances, particularly in the lungs (bronc broncho-pneumonia, inflammatory œdema of the lungs), which often on two to three days afterwards, and may or may not prove fatal. important from this point of view to use pure ether which has not decomposed by air or light. The addition of air even without the acti

light can easily give rise to decomposition products (oxidation, formation of aldehyde), which irritate the air-passages and cause pulmonary inflammation. I keep the ether that is used for anæsthesia in small dark bottles, containing about 150 cubic centimetres, which are kept filled, protected from the light, and stored in a cool place. Since I have used only pure ether with no decomposition products, I have not observed any signs of irritation within the air-passages. According to Nauwerk, Grossmann, and Hölicher, ether pneumonias are, generally speaking, due to unskilful etherisation—i. e., they are caused by aspiration of mucus which is filled with bacteria. As a matter of fact, one should prevent the saliva from collecting in too large amounts, and the patient's head should be lowered, in order that the mucus may not be aspirated into the bronchi. Ether should not be used at all in diseases of the respiratory passages and in teething children. Furthermore, ether should not be employed when the thermo-cautery is to be used about the face and neck, nor in protracted operations about the mouth, jaw, nose, or throat, when the mouth and nose have to be kept uncovered. If in the latter case the etherisation has to be interrupted too early or too often, a complete narcosis can not be obtained. For this reason chloroform is better for long operations on the face and neck. Sänger and Quercain have drawn attention to the possibility of hæmorrhages in old people in consequence of the increased arterial pressure. The assertion that ether more frequently gives rise to nephritis or albuminuria has been shown to be incorrect (see page 35). The statistics regarding the frequency of the transitory albuminuria following the use of ether show a variation with the different anæsthetics of from 10 to 47.6 per cent. In the case of chloroform they vary from 38.06 to 80 per cent. Chloroform seems to be more harmful to the kidneys than ether (Babacci and Bebi). Thomsen and Kemp, however, claim that their researches show the opposite. Both chloroform and ether should be used with great caution in diseases of the kidney, as nephritis that is already present is made worse by both drugs.

The manifestations of ether narcosis resemble those of chloroform narcosis, but the action of the drug is not so lasting. During ether narcosis the great amount of saliva secreted is troublesome, stertorous breathing often occurs, and not infrequently a thick white foam issues from the mouth and nose. As the result of the dilatation of the cutaneous vessels, an increased warmth, redness, and cyanosis occur. At times a transitory exanthema in the form of broad, roseola-like spots, makes its appearance, soon after the beginning of the etherisation, in the region of the neck and chest. Finally, mention should be made of the great inflammability of this drug—a circumstance which increases the difficulty of giving it at night or in operations where the galvano-cautery or thermo-cautery is to be used. Kappeler relates the case of an eighteen-year-old girl, in Lyons, who was etherised in order to apply the cautery. Suddenly, as the surgeon was about to use the cautery on his patient, the ether vapour ignited, setting fire to the cone filled with ether which was being held over her mouth and

nose, and the face of the patient became enveloped in flames. Ter rible burns, involving the tissues down to the bone, were the result o this accident, and the surgeon, in his efforts to extinguish the flames sustained no inconsiderable injuries.

The other consequences of ether narcosis—the nausea and vomiting —are the same as in chloroform narcosis. Sometimes, as already men tioned, there have been observed bronchitis, broncho-pneumonia, dis turbances of respiration (asphyxia, Cheyne-Stokes breathing), and a collapselike condition, especially after prolonged operations. The col lapse from ether may, however, be a result of the cooling off of the sur face of the body. The disturbances on the part of the respiratory organs may not disappear until two to three days after the operation The largest amount of ether has usually left the body one hour afte completion of the anæsthesia. The patient sometimes remains asleep for an unusually long time afterwards, while hysterical patients may become very restless and excited.

On account of the great volatility of ether a special mask or con is necessary for administering the same. There are a large number o cones in use.

Clover's consists of three closely connected parts—a metal vessel to hold the ether, a rubber bag, and a mouthpiece. The lower half o the metal vessel is surrounded by a water tank closed by a screw valve

Fig. 31.—Juillard-Dumont's ether-cone.

Fig. 32.—Wanscher's ether-cone.

the tank being intended to keep the ether from cooling off too much Dumont's modification of Juillard's mask consists of two metal frame placed one over the other and connected by a hinge, the outer on being covered with oilcloth. Between the two frames is placed a piec

of cloth or flannel. The mask is large, and covers the whole face. Over it is placed a folded towel to prevent the evaporation of the ether.

Wanscher's apparatus is shown in Fig. 32. It consists of a cone and a rubber bag for taking up the ether vapour. Grossmann has modified this apparatus by inserting a wire frame, so that the rubber bag does not collapse (Fig. 33). Gehles's apparatus can be folded together and easily carried in the coat pocket. Just as in the case of chloroform, apparatus have been constructed which make it possible to give the patient a specified mixture of ether vapour and air (Dreser and others). In order not to be disturbed by the cone during operations on the face, we can insert a rubber tube into the mouth or nose, and connect it with Junker's or Kocher's apparatus.

Fig. 33.—Grossmann's ether-cone.

The same precautions are necessary in etherising as in giving chloroform. In adults I inject 0.01 to 0.03 morphine hypodermically from ten to twenty minutes before beginning the ether. The patient's head should be inclined somewhat backwards, in order that the increased amount of saliva may not flow into the air-passages and give rise to aspiration pneumonia. For the same reason one should prevent the mucus from collecting in too large amounts in the mouth and throat by swabbing out the same at frequent intervals. The administration of ether should be "pushed" more than is customary with chloroform, since it acts less powerfully. In using Juillard's cone, for example, considerable ether should be poured on at first (30 to 50 cubic centimetres, for instance), and it is usually possible to obtain complete anæsthesia with this amount, particularly in children. Dreser has examined the mixture of air and ether under Juillard's cone during etherisation, and determined that there is neither an alarming accumulation of carbonic acid nor a dangerously small percentage of oxygen. Other surgeons prefer a more gradual way of giving the ether to this asphyxiating method—i. e., the cone is brought near the face more gradually, and the amount of ether given is slowly increased. In some individuals this method is undoubtedly preferable. The respiration is the chief thing to be watched in giving ether, but the pulse should not be neglected. If the respiration suddenly stops in consequence of paralysis of the respiratory centre from too much ether, the latter should be stopped at once and artificial respiration begun. The latter

is usually successful if the disturbance in breathing is noticed promptly. In case also of spasm of the respiratory muscles, causing the face to become very blue, the ether should be temporarily discontinued.

A subsequent stage often follows the real anæsthesia, in which the loss of sensation continues, but the patient has returned to consciousness. The same thing occurs in the use of bromethyl (see page 47). For the treatment of the disturbances following etherisation (vomiting, etc.), see page 29, Chloroform Anæsthesia.

Action of Ether on the Laryngeal Muscles.—Semon and Horsley have confirmed by their experiments the observations made by others, namely, that the posterior crico-arytænoid muscles are the first to lose their power of contraction after death and in cases of organic disease or injury to the centres or to the branches of the motor nerves of the larynx.

In deep ether narcosis there is abduction of the vocal cords; and when the narcosis is slight there is adduction, no matter whether the recurrent laryngeal nerve is divided or not.

Narcosis per Rectum.—Mollière and Iversen have successfully produced ether narcosis by introducing the vapour into the rectum by means of a rubber tube connected with Richardson's ether vapouriser. Mollière also passed into the rectum a rubber tube which was connected with an ether flask standing in water at 50° C. (112° F.), thus causing the ether to boil. Mollière mentions as advantages of rectal anæsthesia the lack of a stage of excitement, the possibility of exactly regulating the amount of ether given, and the convenience of the method in operations on the face.

Rectal etherisation was first used by Pirogoff forty years ago. Recently, Starcke has also investigated the method and has urged its further trial.

The other compounds of ethyl have not become established as anæsthetics; among them are ethyl chloride, ethyl bromide, ethyl nitrate, ethylidene chloride, ethyl aldehyde or aldehyde, Aran's ether, acetic ether, etc.

§ 15. **Laughing-Gas Narcosis.**—Among the inorganic compounds, nitrogen monoxide or laughing gas (Davy), is the best anæsthetic. Nitrous oxide, N_2O, is a colourless gas with a slightly sweetish taste and smell. It is made by cautiously heating ammonium nitrate, which breaks up at a temperature of 170° C. into water and nitrous oxide. The anæsthetic action of laughing gas is not unpleasant, and there are almost no disagreeable after-effects; nausea and vomiting scarcely ever occur. But it is not entirely free from danger, though it is much less dangerous than chloroform or ether. Statistics show that out of four to five million cases where it has been used, only fourteen deaths have been recorded (E. H. Hankel). In a few instances it has caused epileptic fits, great excitement, deep cyanosis, and similar phenomena, but in general the drug is relatively free from danger. After making investigations with the spectroscope, Ulbrich came to the conclusion that nitrous oxide formed a chemical combination with the hæmoglobin,

and so could become dangerous; but Preyer, Buxton, MacMunn, and Rothmann were unable to confirm these statements of Ulbrich's, as the duration of the narcosis is too short, therefore these authors consider that nitrous oxide is not a dangerous anæsthetic. Still, a narcosis of long duration is not to be recommended. The drug is suitable for short operations, particularly the extraction of teeth, and hence laughing gas is to-day the best anæsthetic for the dentist, and in England and America it is used with very great frequency. In fifty to sixty seconds the anæsthesia is so complete that minor operations, like the extraction of teeth, can be performed without pain. Recovery from the narcosis is equally prompt, and without unpleasant after-effects. Laughing gas has also been frequently used during parturition, and with good results (Zweifel). The gas is inhaled either pure or mixed with air. For the sake of economy the gas is now stored in a gasometer or rubber bag so arranged that the expired gas can be used over again.

Narcosis with Oxygenated Laughing Gas.—Klikowitsch, Döderlein, Schreiter, and Hillischer have recommended an oxygenated nitrous oxide (nitrous oxide with twenty per cent. oxygen) for narcosis instead of the pure nitrous oxide. It is suited especially for protracted narcosis in which major surgical operations can be performed. The two gases are stored in two separate gasometers and are mixed immediately before inspiration. The apparatus is so arranged that the proportion of the mixture can be altered at any moment.

Narcosis with Oxygenated Laughing. Gas and Increased Atmospheric Pressure.—P. Bert has recommended the administration of a mixture of nitrous oxide with fifty per cent. of air under increased atmospheric pressure (two to three atmospheres). With nitrous-oxide narcosis conducted under these conditions of increased atmospheric pressure, the operator, his assistants, and the patient must enter a specially prepared room, where the air can be compressed and the patient inhale the nitrous oxide. This atmosphere of compressed air is said not to be very disagreeable for the operator and his assistants.

The advantages claimed for nitrous-oxide narcosis with compressed air are: 1. The absence of a stage of excitement. 2. The ease of maintaining for a long time any desired degree of narcosis. 3. The prompt return of consciousness. 4. The absence of vomiting. 5. The complete freedom from danger. For combined laughing-gas and ether anæsthesia see below.

Other Anæsthetics.—The other inorganic compounds which have been tried as anæsthetics, such as nitrogen, carbonic acid, bisulphide of carbon, etc., should be abandoned.

§ 16. **Mixed Narcosis and other Anæsthetics.**—The above-mentioned anæsthetics have been frequently mixed with each other. The Vienna school recommends a mixture of three parts ether and one part chloroform. Linhart used a mixture of four parts chloroform and one part

absolute alcohol. Billroth favours a mixture of three parts chloroform, one part ether, and one part absolute alcohol. The English Committee on Chloroform has tried three different mixtures: 1. One part chloroform and four parts ether. 2. One part chloroform and two parts ether. 3. One part alcohol, two parts chloroform, and three parts ether.

The first mixture acts like unmixed ether, while the other two are almost the same, and, while inducing a speedy loss of consciousness, interfere less with the functions of the heart than does pure chloroform. I once used almost exclusively a mixture of one hundred parts chloroform, thirty parts ether, and twenty parts absolute alcohol. At present I prefer a mixture of equal parts of chloroform and ether.

Different authors have recommended a mixture of oxygen with chloroform, ether, or laughing gas, etc. Many surgeons combine the chloroform and ether narcosis, beginning the narcosis with chloroform and keeping it up with ether, or *vice versa*. I use the chloroform-ether narcosis a great deal in adults, and am well satisfied with it. A combination of laughing gas and ether is now being used. This does away with the stage of excitement and the irritating action of the ether. Laughing gas is used first, and then ether is substituted. Very rapid anæsthesia is said to be produced by using first bromethyl and then chloroform.

Morphine-Chloroform Narcosis.—The morphine-chloroform narcosis —a combination first tried by Nussbaum—is of considerable value. It is especially suitable for alcoholic cases, and for individuals in whom a well-marked stage of excitement is to be expected. One, two, or three centigrammes of acetate of morphine are given in aqueous solution, hypodermically, about ten to twenty minutes before the narcosis is begun, or immediately preceding the latter; afterwards, a second injection may be given during the stage of excitement, or later in the progress of the narcosis, particularly if the operation is protracted. The advantages of a mixed morphine-chloroform narcosis (which I only use on adults) are as follows: The narcosis progresses more quickly and quietly; there is less mental worry; the stage of excitement is shortened, or completely absent; the respiration is more regular, and a smaller amount of chloroform is required. It is possible in this morphine-chloroform narcosis to render the patient insensible to the pain of the operation, while the reflexes are retained, as well as control of the voluntary muscles, and the patient remains in full possession of his senses; he hears and answers any questions which may be put to him. This state of narcosis is very valuable for operations on the face, mouth, pharynx, and nose, as the patient will, when told

to, eject the blood collecting in his mouth, or swallow it, as the reflex excitability of the muscles of the pharynx and palate is not lost. If it is desired to obtain this condition of semianæsthesia, one and a half or two centigrammes of acetate of morphine should be injected about ten minutes before the narcosis is begun, after which the patient should be chloroformed till the stage of excitement is reached, and then the amount of chloroform administered should be gradually diminished.

As objections to the combined morphine-chloroform narcosis, I have noticed that the morphine sleep following the operation has a bad influence upon breathing, and sometimes permits the inhalation of foreign matter with a resulting aspiration pneumonia.

Langlois and Maurange combine chloroform with oxysparteine. Three to four centigrammes of oxysparteine with one centigramme of morphine are injected a quarter of an hour before beginning the chloroform. The narcosis comes on promptly, can be kept up by the use of very little chloroform, and the heart's action is very regular.

Instead of injecting morphine subcutaneously, two to four grammes of chloral hydrate can be given by mouth some time before the operation. This chloral-chloroform narcosis resembles quite closely the morphine-chloroform narcosis.

Other surgeons inject morphine, atropine, and chloral—e. g., a hypodermic syringeful, containing 2 centigrammes of morphine, $\frac{4}{10}$ milligramme of atropine, and 1 centigramme of chloral. Fränkel injects, one quarter of an hour before beginning the chloroform, 1 to $1\frac{1}{4}$ cubic centimetre of a solution containing morphine, 0.15; atropine, 0.015; chloral hydrate, 0.25; distilled water, 15.0. Morphine is supposed to act as a stimulant to the heart, and atropine upon the respiration.

In ether anæsthesia, also, I inject 0.01 to 0.03 morphine from ten to twenty minutes before beginning the anæsthetic, and find it a very good combination.

Oré, Deneppe, and Van Wetter have repeatedly produced anæsthesia by injecting chloral hydrate into a vein, but this is entirely too dangerous to be made use of.

Other Anæsthetics.—*Acetal.*—Recently Von Mering has tested the anæsthetic powers of acetal, and particularly dimethylacetal and diethylacetal. He strongly recommends a mixture consisting of two volumes of dimethylacetal and one volume of chloroform as being less dangerous than chloroform, since it has less of the paralysing effect on the heart's action. Lücke states that the narcosis induced by dimethylacetal and chloroform has no marked stage of excitement, and only exceptionally causes vomiting.

Bromethyl.—Inhalations of bromethyl are sometimes used in operations of short duration, such as extraction of teeth. It is just as dangerous as the other anæsthetics. Gurlt estimates the mortality at 1 to 5,228; and Borscha 1 to 20,000. According to Gilles the fatal cases, which result usually from

cardiac paralysis, are due to the use of an impure preparation, or too large a dose, or to the employment of bromethylene by mistake.

Bromethyl (ethyl bromate), bromate of ether, C_2H_5Br, is a colourless liquid smelling like ether and having a neutral reaction. It is neither inflammable nor explosive, but evaporates very rapidly when exposed to the air. Only chemically pure bromethyl should be used for narcosis, and hence it should be tested beforehand. When pure bromethyl is poured on the hand it immediately evaporates without leaving a greasy feeling. On the addition of one per cent. nitrate of silver to an impure preparation a cloudiness appears, which in a short time becomes milk white (Pomeranzer). The method of conducting the narcosis with this drug is the same as with ether and chloroform, and I have used it with success in short operations—extraction of teeth, etc.

Bromethyl acts better when access of air is prevented as far as possible by laying a piece of folded cloth or compress over the inhalation mask, or, still better, by using the Juillard-Dumont ether mask with its oilcloth cover. In children ten to fifteen grammes and, in adults ten to thirty grammes, are necessary to produce the narcosis, which usually comes on in about one half to one and a half minutes and lasts one and a half to three minutes, and is seldom followed by disagreeable after-effects, though I have several times seen vomiting. During the next two or three days the breath has an unpleasant smell of garlic.

The use of bromethyl in conjunction with chloroform has been recommended by a number of surgeons. Bromethyl is used first, and then chloroform. The narcosis is said to take place quickly, and often without excitement. The patient comes out of the anæsthesia promptly, and there are no subsequent disturbances.

Ethyl Chloride.—Soulier and Ludwig recommend ethyl chloride ("Kelen") for short operations. It was used sixty-six times in Hacker's clinic.

Bromethylene should be entirely rejected. Szuman observed a fatal instance of its use in a man twenty-seven years old, who was given by mistake thirty grammes of bromethylene instead of bromethyl.

Bromoform.—Von Horoch has studied the anæsthetic effect of bromoform, but the results obtained do not, as yet, seem to justify its use in surgery.

Pental.—Amylene, which has been recently given the name of pental (C_5H_{10}) by C. A. Kahlbaum, has been much used for narcosis in short operations. The method of its administration is the same as that of chloroform and anæsthesia occurs in from fifty to ninety seconds. It has no influence on the heart and respiration, and the patient regains consciousness in three or four minutes, while sensation remains lost for several minutes longer. Pental is inflammable, like ether. Recent experience with it shows that it is not to be recommended as an anæsthetic. Asphyxia, syncope, albuminuria and hæmoglobinuria have been observed, and a number of deaths have occurred.

Narcosis resulting from Irritation of the Laryngeal Mucous Membrane.—Brown-Séquard made some very interesting investigations which show that general anæsthesia may follow irritation of the laryngeal mucous membrane

with carbonic acid and chloroform, and he amputated the thigh of a rabbit in this way without pain. The irritation of the laryngeal mucous membrane is the essential thing; after division of the superior laryngeal nerve anæsthesia does not occur. If the superior laryngeal nerve on only one side is cut, and the carbonic acid or chloroform is then applied, there results simply a slight diminution of sensation on this side, while upon the other there is a condition of complete or partial anæsthesia; on one side a toe could be amputated without the least pain, but on the other side the operation caused the most violent manifestations of pain.

§ 17. **Local Anæsthesia.**—For producing local anæsthesia of a particular part of the body, the methods are: compression, cold, electricity with or without the addition of a narcotic, and, above all, the local application of certain drugs. Frequently, in former times, the vessels and nerves of an extremity were tightly compressed by a tourniquet, which caused a local though certainly insufficient anæsthesia. Cold is also a good local anæsthetic. James Arnott was the first to employ a freezing mixture of ice and salt; but since 1866 Richardson's ether spray has come into much more general use, and is far more convenient.

The ether is sprayed over some particular spot on the skin for one or two minutes, causing the skin to become first red, then, as the evaporation of the ether produces cold (— 15° C.), it becomes white, parchmentlike, and without feeling. But the loss of sensation is principally limited to the skin. This method is suitable for small operations—opening abscesses, puncturing cysts, and for operations on the extremities after the latter have been tied off with a tight elastic tourniquet. By the use of a fan the anæsthesia is hastened, and by interrupting the circulation the freezing of the tissues is favoured. Robbin's preparation of ether, which is practically methylene bichloride, works better than the ordinary sulphuric ether. The attempt to perform major operations under ether spray has not proved very successful.

Ethyl chloride is used as a substitute for ether in the freezing method; but it cannot very well be employed on an open wound, as it is excessively painful.

A spray of methyl chloride is used in the same way as the ether spray, especially in France.

Cocaine.—At present we have in cocaine a most excellent local anæsthetic, which was first used in ophthalmology by Koller. Solutions of cocaine easily become mouldy, and hence they should be prepared in small quantities, and some bichloride of mercury or carbolic acid added. It is best to have the solution freshly prepared, or at most two to three days old. The intensity and duration of the anæsthetic action can be increased by neutralising the freshly prepared

solution by the addition of carbonate of soda, and warming it to 50° 55° C., or by giving a hypodermic injection of morphine a quar of an hour before using the cocaine. For operations on mucous me branes aqueous solutions of five to twenty per cent. are used. It dropped into the conjunctival sac, and painted upon other muco membranes. In operations on the external integument 5 to 15 mil grammes are injected into and beneath the skin. I use for this pu pose a weak solution (one per cent.), and inject from one to t syringefuls, depending upon the case. The injections can be ma under ether spray, and, in case of the extremities, elastic constriction employed. A distinction is made between *direct* and *regionary* loc anæsthesia. In direct anæsthesia the injection is made at the poi where the cut is to be made, while in regionary anæsthesia it is ma at some distant point along the main sensory nerve. Regionary c caine anæsthesia is only successful in those places where the bloc supply can be cut off and the peripheral sensory nerve anastomos can be excluded. This is mainly true of the fingers and toes. Re gionary anæsthesia is produced as follows: The base of the finge or toe is tied off with a piece of rubber tubing and a one-per-cent. solu tion of cocaine is injected close to the constricted point and in th direction of the tip of the finger or toe. Complete anæsthesia require from three to six minutes and sometimes longer, and hence one shoul wait that length of time before beginning the operation. In *direc* anæsthesia loss of sensation usually takes place immediately. Region ary cocaine anæsthesia can also be employed on the hand and foot, bu it is necessary to wait a somewhat longer time before beginning th operation. The anæsthetic effects of cocaine last from ten to twenty minutes.

Cocaine is not free from danger, and should hence be employed with great care. Symptoms of poisoning frequently occur, consisting of dizziness, excitement, unconsciousness, convulsions, and pallor of the face, with a weak and rapid pulse. Death has occurred in not a few cases, even after the injection of cocaine into the ureters for facilitating catheterisation. Weigand has collected two hundred and fifty cases of acute cocaine poisoning, with twenty-one deaths. The most dangerous method of employing it is to apply a large amount of a strong solution to mucous membranes. Subcutaneous injections, particularly by the regionary method, are much less dangerous. Among twenty-one fatal cases, seven occurred from its internal administration and two after its application within the rectum. To prevent fainting and other cerebral manifestations it is important for the patient to maintain a recumbent position during and immediately after the oper-

ation. Death is usually due to the employment of too large an amount of a strong solution. In the great majority of fatal cases the amount of cocaine injected into the skin was more than twenty-two centigrammes. According to Maurel, the poisonous action of cocaine is due to contraction of the small vessels and the emboli that result therefrom. The maximum dose has been put at three centigrammes. Wölfler considers that the maximum dose for injection about the head should be two centigrammes, and for the extremities five centigrammes. It seems to me impossible to fix a maximum dose for cocaine, as so many individuals are very susceptible to it, while others can take large doses without any bad symptoms. The best antidote for cocaine poisoning is amyl nitrite in the form of inhalations, which should be given at the first signs of cerebral anæmia (Feinberg). Bromide of potassium, morphine, and antipyrine have also been used with advantage. Gautier has not seen any symptoms of poisoning since he began to add nitroglycerin to the cocaine. He uses the following solution: Cocaine, 0.2; aq. distillata, 10; 1 per cent. nitroglycerin, gtt., x.

Schleich's Infiltration Anæsthesia.—Quite recently Schleich's infiltration anæsthesia, which is absolutely without danger, has come more and more into general use. It is possible to perform with it operations of considerable magnitude, such as laparotomies (gastrostomies, etc.), and operations on the joints of half an hour's duration. I have not found it so efficient in inflammatory tissues. The method consists briefly in rendering the tissues to be operated on bloodless (ischæmic)—i. e., insensitive—by injection of a morphine-cocaine solution. On the extremities the parts may, in addition, be rendered bloodless by an Esmarch bandage; but this should not be done until after the solution has been injected, because otherwise the blood cannot be forced out of the tissues by the anæsthetising fluid, and the injection is painful on account of the great tension of the tissues. Schleich has recommended three different solutions: Solution I: Cocaine, 0.2; morphine, 0.025; sodium chloride, 0.2; aq. distillata, 100. Solution II contains half as much cocaine as solution I. Solution III contains one tenth as much cocaine as solution I, and only 0.005 morphine. Solution II usually suffices. The injections are made under the strictest asepsis and with a proper needle (Schleich's or Braun's). The first injection causes the formation of a tense white wheal, and the needle is reinserted on the edge of this wheal, and so on. The subjacent tissues are then made anæsthetic by injecting them at once, or after making the incision through the skin. Braun recommends the following solution for Schleich's anæsthesia: 0.1 eucaine B (see page 52); 0.8 sodium chloride; and 100 water at body temperature. As much as three hundred cubic centimetres of this solution can be injected at one operation. It is not decomposed by repeated boilings. General anæsthesia with Schleich's mixture (consisting of chloroform, ethyl chloride, and ether in the different proportions) has not met with general favour. For the fingers and toes the method of cocainisation combined with elastic constriction is distinctly preferable to Schleich's method. One disadvantage of the latter is that the

topographical relations are sometimes disturbed by the œdema, and the bor der line between the healthy and diseased tissues may be indistinct.

Cocaine in Conjunction with the Galvanic Current.—Wagner and Herzog have anæsthetised the unbroken skin with cocaine in conjunction with the galvanic current. The anode, previously dipped in a cocaine solution, is placed upon the skin a certain distance from the cathode, and, after the current has been turned on, the portion of the skin lying between the electrodes becomes anæsthetised. The strength of the current was two to four milli-ampères. The method depends upon the cataphoric action of the current in moving fluids from the anode to the cathode.

Cocaine with Ethyl Chloride.—E. Nagy has good results from the use of cocaine in combination with ethyl chloride for the extraction of teeth (one third to one half a syringeful of a freshly prepared two-per-cent. solution of cocaine). The gum is sprayed with the ethyl chloride for about a minute after the injection of cocaine, until a thick layer of white crystals forms.

Other Anæsthetics possessing a Local Action.—The local application of chloroform, opium, saponin, amylene, carbon bisulphide, etc., or the use of the constant or induced current in combination with chloroform, tincture of aconite, the alcoholic extract of aconite, etc., have all been found to be of little value. On the other hand, I have had good success with menthol (in combination with lanolin or olive oil). Menthol is not a dangerous drug, and a whole hypodermic syringeful of a ten- to twenty-per-cent. solution of menthol in olive oil can be injected into and under the skin. The ether spray may be combined with it. The local application of a mixture of equal parts of menthol and lanolin has also been found efficacious.

As a substitute for cocaine, Claiborne has recommended stenocarpin in a two-per-cent. solution. It is a very expensive alkaloid.

Erythrophlæine has been used as a local anæsthetic, but is of slight value. Reid recommends drumine, an alkaloid from euphorbia. Vámossy uses anäsin (aqueous solution of acetone-chloroform), which in a one-per-cent. aqueous solution corresponds in action to 2 to 2.5 per-cent. cocaine. Eucaine is employed a good deal in solutions of two to ten per cent. Two grammes can be injected at one time without harm. The advantages of eucaine over cocaine are said to be that it is less poisonous, cheaper, more stable, and can be sterilised, as the solutions are not decomposed by heat. It does not act like cocaine, by producing anæmia of the tissues, but, on the contrary, produces hyperæmia. I do not find it so efficient in preventing pain as cocaine. Braun recommends eucaine for infiltration anæsthesia.

CHAPTER III.

THE PREVENTION OF LOSS OF BLOOD DURING AN OPERATION.—ESMARCH'S ARTIFICIAL ISCHÆMIA.

The prevention of loss of blood in all operations.—Different methods: Digital compression of the main artery; tourniquets; ligation, or "Umstechung," tearing, tying-off, or clamping of adhesions or of blood-vessels before they are divided.—Esmarch's artificial ischæmia in operations on the extremities: its technique; its advantages and disadvantages.—Modifications of Esmarch's method.—The application of the method to various parts of the body.—Historical.

§ 18. **The Prevention of Loss of Blood during an Operation.**—In all operations we must bear in mind the necessity of making the loss of blood as small as possible, particularly in the case of weak or anæmic individuals, in children less than a year old, and in the aged. If this rule is not taken to heart many a patient will perish simply from loss of blood.

The modern surgeon has many ways of saving blood during an operation. Frequently the artery supplying the part in question is ligated before the operation is begun, as, for instance, both lingual arteries in removal of a cancerous tongue; or the artery is compressed by the finger only while the operation lasts (digital compression); again, in some cases, the vessel may be secured by a suture passed through the skin and under the vessel (percutaneous ligation *en masse*).

In the extirpation of new growths and tumours connected to the surrounding parts by vascular and more or less strong adhesions, the vessels, or the vascular adhesions, are seized by self-locking pincers or artery clamps, and the vessels, or vascular strips of tissue, after being secured by two clamps, or a double ligature of silk or catgut, are divided between them.

This procedure is much facilitated by tearing through the weak, non-vascular attachments, which yield readily to the pressure of the finger, while the stronger and more vascular parts resist, and can be felt and more readily recognised.

Lacerated wounds bleed less than incised ones. If a large vessel is wounded, the bleeding from it is at once stopped by the pressure of

the finger, and the vessel is then seized by an artery clamp and divid between a double ligature, one of which closes the central and tl other the peripheral open end of the vessel. In other cases, to pr vent loss of blood, the cautery iron or galvano-cautery is used, et The technique of this method is mentioned later (§ 25).

§ 19. **Esmarch's Artificial Ischæmia.**—The bloodless method of ope ating on the extremities has been perfected by the ingenuity of E march. In removing an extremity by Esmarch's method, not only we save the blood in the limb to be amputated, but also, during tl operation, bleeding is almost entirely prevented by the elastic constri tion of the limb previously made anæmic. The so-called tourniqu (Fig. 34) was formerly used to check the flow of blood during amput tions, or the same end was attained by compressing the main artery the part with the fingers (digital compression). (Figs. 35, 36.)

At the present time, for rendering operations on the extremiti bloodless, we use Esmarch's very simple and efficacious method, whi consists in tying off the member after it has first been emptied

Fig. 34.—Petit's screw tourniquet.

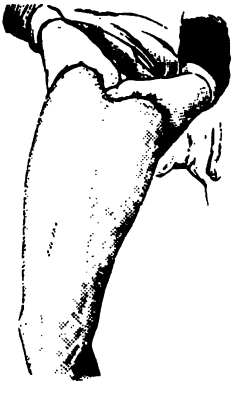


Fig. 35.—Digital compression of the femoral artery.

Fig. 36.—Digital compressi of the brachial artery.

blood. The old-fashioned tourniquets and digital compression ha been abandoned for this.

Suppose, for instance, that we wish to perform an amputation the leg. After the leg has been properly disinfected and shaved, it first elevated and then wrapped in a sterilised elastic bandage draw moderately tight, from the toes upward as far as the lower third the thigh. The end of the bandage is then held by an assistant, after the last turn the roll is tucked under the immediately prece ing turn. The bandage should have been previously disinfected l immersion in a solution of one tenth per cent. bichloride or of thr

to four per cent. carbolic. To avoid forcing into the lymph channels any noxious materials, such as tumour germs or pus, etc., the diseased part should not be covered by the wrappings, but carefully avoided;

Fig. 37.—Esmarch's rubber tubing for producing artificial ischæmia.

Fig. 38.—Clamp for the rubber tubing used for producing artificial ischæmia.

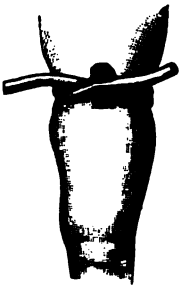


Fig. 39.—Fixation of Esmarch's rubber tubing by means of the clamp.

or, better still, the elastic bandage should in such instances not be used at all.

Finally, Esmarch's rubber tourniquet is wound moderately tight around the limb at the upper termination of the elastic bandage, and the latter is removed. In case the elastic bandage is not used, the extremity is held vertically for a couple of minutes and stroked lightly from above downward to diminish the amount of venous blood, and then the rubber tourniquet is applied. Fig. 37 illustrates the usual form of Esmarch's elastic tourniquet, with a chain and hook for fastening it.

Another way of securing the tourniquet is illustrated in Figs. 38 and 39. The two ends of the rubber tube are inserted in a so-called "tube clamp," which consists of a half-open brass ring fastened to a plate. The ends of the tube are well stretched and forced into the slot, and when relaxed the ends are held tightly pressed together (Fig. 39). In place of the rubber tubing used as a tourniquet one can substitute a piece of linen previously sterilised and moistened. Thus the extremity is emptied of blood up to the lower third of the thigh, and the leg can be amputated as on the cadaver.

At the conclusion of the amputation the principal arteries and veins are clamped and tied. This is quickly done, as the vessels can be easily seen in the bloodless stump. The larger muscular branches of the arteries will be found at the point where the connective-tissue sheaths which envelop the different bundles of muscles cross each other. When all the visible vessels have been secured in the bloodless stump the latter is elevated, and its surface compressed with two or three

aseptic sponges or compresses, while an assistant slowly loosens th Esmarch tourniquet, but is ever on the alert to tighten it again : bleeding should occur at any point. After removal of the tourniqu the hitherto apparently dead extremity becomes bright red. At th same time, unless the stump is elevated perpendicularly and the woun compressed for a couple of minutes, there almost always follows con siderable oozing, because the pressure of the elastic tourniquet produce a temporary vasomotor paralysis which prevents the smaller, unsecure vessels from contracting and closing spontaneously.

When Esmarch's method first came into general use this oozin was thought by many surgeons to be such a serious matter as almost t outweigh the advantages of the method, and others held that the los of blood during the oozing which followed was greater than in the cas of the old methods. Ice-water irrigations, the application of the electric current, injections of ergot into the tissues around the wound, etc., were all practised to prevent this oozing.

I have always been perfectly satisfied with elevating the stump and making pressure on the wound for a couple of minutes with sponges or compresses, and after doing this I have never seen any subsequent oozing worth mentioning, and the patient loses really only a few drops of blood.

Esmarch recommended that drains be put in place, and the wound sutured and dressed antiseptically before removing the elastic tourniquet. This can be done in suitable cases—for instance, in necrosis operations or extirpation of tumours. I never adopt it in amputations and resections, but always check the bleeding first. Whichever plan is adopted, the extremity which has been operated upon should, after the dressings have been applied, be invariably placed in an elevated position for the next twenty-four hours, as by this means the oozing will be minimised.

This elevation of the stump has also an antiphlogistic and analgesic effect, and therefore can be used with great advantage in various forms of inflammatory processes on the extremities. When the extremities are elevated there is regularly a diminution in the height of their temperature. According to Meule, for an elevation lasting sixty minutes, the maximum diminution is 7.2° C. (12.9° F.), the minimum 2° C. (3.6° F.). Furthermore, the blood pressure is lessened, and the frequency of the pulse averages a decrease of nine beats to the minute. Upon this also depends the hæmostatic power of elevation.

The advantages of Esmarch's method consist in the actual saving of blood and in the possibility of operating in a dry wound without the need of sponges. Moreover, fewer assistants are required, and

everything can be plainly seen—a matter of much importance in searching for a small foreign body, like a needle point, or for a wound in a blood-vessel. Furthermore, Esmarch's elastic-tube tourniquet can be applied to any part of the extremities, which was not the case with the old-fashioned appliances.

The method has really no serious disadvantages. It has been shown how easy it is to stop the oozing which follows removal of the elastic tourniquet and which has been found fault with by so many surgeons, and I do not yet consider it proved that the edges of wounds, for instance, in amputations, become more often necrotic after using Esmarch's method (König). Sometimes there has been observed a paresis of the nerve trunks of shorter or longer duration, especially after tight constriction of the arm, and in exceptional cases cutaneous flaps have died from want of nourishment. But these mishaps are not to be ascribed to the method, but to its unskilful application—i. e., to too much compression.

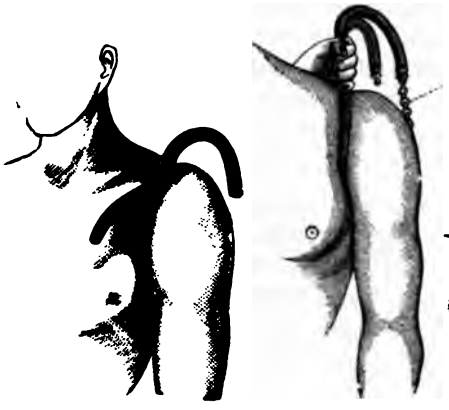
The Increased Power of Absorption possessed by the Tissues after Removal of the Elastic Tourniquet.—Wölfler experimented on dogs with potassium ferrocyanide, cyanide of potassium, strychnine, etc., to determine whether, in a limb rendered anæmic by Esmarch's method, absorption occurs up to the point of application of the rubber tubing, and how the absorption is affected by removal of the constriction. It appeared that while the elastic tourniquet remained in place no absorption occurred, but that after it was removed absorption was very much accelerated. Therefore Wölfler recommends that the constriction be maintained until the wound has been dressed antiseptically and elevated. All moistening of the wound with such poisonous substances as carbolic acid, bichloride of mercury, and the like, should be done before the removal of the elastic tourniquet.

Autotransfusion.—After great losses of blood, which endanger life, Esmarch's bandage may be applied to the extremities in order to force the blood in the latter towards the heart, and so avert a threatened heart failure or cerebral anæmia (so-called autotransfusion).

For how long a time can Esmarch's constriction be kept up with impunity?—At present this question cannot be satisfactorily answered. Esmarch has maintained his artificial anæmia on human limbs for two hours and a quarter without doing any damage. If the constriction is kept up for three to four hours, the vitality of the tissues cut off from the circulation may be imperilled. The results of animal experimentation cannot be applied to man, and therefore I shall omit a discussion of the same.

The following is a brief summary of the technique for applying Esmarch's constriction to particular parts of the body. The method of using Esmarch's elastic tourniquet on the shoulder for high amputation

of the arm, or for removal of the arm at the shoulder joint, is illustrat in Fig. 40, *a* and *b*. The Esmarch elastic tourniquet cannot be us for disarticulation of the arm—e. g., for a large tumour—because he



a *b*

FIG. 40.—Esmarch's tubing applied at the shoulder.

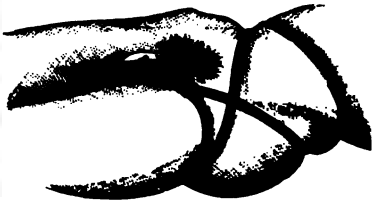


FIG. 41.—Application of Esmarch's rubb tubing about the hip.

the artery would be compressed against the head of the humerus, ar as soon as the latter was freed from the joint the tourniquet wou be useless. Therefore it is better in such a case either to ligate tl subclavian artery first and then proceed with the disarticulation, or perform a high amputation of the arm, using Esmarch's constrictir

FIG. 42.

FIG. 43.

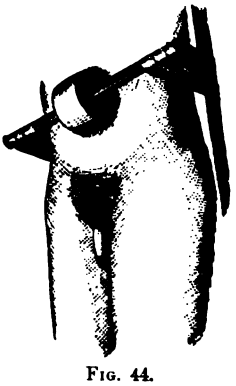


FIG. 44.

FIGS. 42–44.—Compression of the aorta (Esmarch).

rubber tube, then ligate the vessels in the stump, and finally remo the remaining portion of the humerus subperiosteally. It is manifest not wise to carry Esmarch's elastic tourniquet around the thorax in tl

form of a shoulder spica, as the thorax would be compressed during the narcosis. The manner of applying the elastic tourniquet in the region of the hip, for amputation of the thigh, is illustrated in Fig. 41. The pressure on the femoral artery can be increased by placing a cloth pad or roller bandage beneath the elastic tube over the artery. For amputation of the hip joint, Esmarch recommends compression of the aorta after having previously emptied the intestines (Figs. 42 to 44). The following plan (Volkmann's) is better: After applying the rubber bandage tightly up to the inguinal region, the elastic tourniquet is carried from the femoro-scrotal commissure in the direction of Poupart's ligament obliquely outward to the semilunar notch of the ilium between its two anterior spines. During the operation the tube is held in the hands of an assistant, or, better still, it is secured in position by three pieces of bandage tied around it and drawn upward to prevent it slipping down after division of the muscles. Another way is to apply the rubber tubing about the thigh and pelvis (Fig. 41), perform a high amputation of the thigh, arrest the hæmorrhage in the stump, and then remove the stump of bone through a longitudinal incision over the trochanter. Esmarch's artificial ischæmia, combined with local anæsthesia, is excellent for small operations on the fingers and toes. In operations on the male genitals Esmarch winds a small rubber tube around the base of the scrotum and penis, and, crossing its ends over the mons Veneris, he carries them around behind and ties them together over the sacrum. But I do not consider the tourniquet necessary, particularly in amputation of the penis, where compression of the part with the fingers is sufficient.

Langenbeck has also used Esmarch's method in operations on the scalp. The head is first wrapped in a gauze bandage, according to the rules for applying the "Mitra Hippocratis" (see § 50, Bandaging); then the rubber bandage is passed around the forehead and occiput and the gauze bandage cut off.

History of Artificial Anæmia.—Constriction of an extremity above the point of amputation was much used long before the invention of the tourniquet by Morell and J. L. Petit, and Ambroise Paré practised the method in the sixteenth century. Even artificial anæmia is said to have been used here and there, though never so perfectly as by Esmarch. Grandesso Silvestri appears to have been the first to envelop a limb with an elastic bandage, and, instead of a tourniquet, to have used an elastic tube. But little notice was taken of Silvestri's proposition, and then Esmarch, without knowing what Silvestri had done, continued the same method. The honour of bringing artificial ischæmia to its present perfection is certainly due to Esmarch.

CHAPTER IV.

GENERAL RULES FOR PERFORMING AN ASEPTIC OPERATION AND FOR TI AFTER-TREATMENT OF THE PATIENT.

a. Behaviour of the surgeon during the operation. *b.* Experienced assistance. Close observance of antiseptic principles. *d.* Asepsis and antisepsis. *e.* Acc dents during the operation: (1) Syncope; (2) convulsions; (3) hæmorrhage. Operations on "bleeders." *g.* Death from entrance of air into the veins. Death from other causes. *i.* Supplement: (1) After-treatment of operative case (2) the most important causes of death after operation.

§ 20. **Performance of an Aseptic Operation.**—After the above-men tioned preparations for an aseptic operation have been made, and th patient has been anæsthetised, every operation should be performe quickly, without hesitation, and with the most scrupulous regard t antiseptic precautions. It is not of so much importance now as it wa before the introduction of anæsthesia to perform an operation witl great rapidity in order to spare the patient pain. But even at the present time we perform operations as quickly as possible, because we know that an operation by lasting for too long a time may prove fatal to the patient. Especially is this true of operations in the peritoneal cavity, which may prove fatal shortly after the operation because of the long-continued loss of body heat (Wegner). The most important conditions for rapid and safe operating are: a careful examination of the patient before operation; a certain diagnosis; accurate anatomical knowledge; and a natural manual dexterity. A sharp knife and proper instruments scrupulously clean are, of course, indispensable.

As we are fully conversant of the fact that all wound diseases are the result of infection by bacteria, and that the life of our patient may be placed in great danger if the bacteria enter the wound, we must always observe the strictest asepsis; no unclean finger, no instrument which has not been previously disinfected, must come in contact with the wound. The hands and clothing of the operator and his assistants, the instruments, sponges, or gauze pads, the field of operation, etc., are sterilised after the method described in § 6, and everything around the area to be operated upon is covered with aseptic compresses or

towels. Beside the operator and his assistants there should be suitable basins for holding clean disinfecting solutions, especially three-per-cent. carbolic or 1 to 1,000–5,000 bichloride. Particular care must be taken that the wound is not contaminated directly or indirectly by any spectator's hands which have not been disinfected—for instance, by allowing him to pass instruments, sponges, etc. Most carefully sterilised sponges or pads are used to keep the wound dry, but they should bring nothing into the wound from the surface surrounding it. For operating upon the cavities in the body—e. g., the mouth, vagina, etc.—sponge holders are required.

Fig. 45. Sponge holder.

An excellent pad or sponge holder is illustrated in Fig. 45. By pushing up the ring the jaws are closed, and so firmly hold the sponge or pad. The use of too concentrated antiseptic solutions should be avoided, for they may cause dangerous or even fatal poisoning. Lister's antiseptic spray of three-per-cent. carbolic acid is no longer used during the operation. We operate by the dry method as far as we can, and should make it our aim to irritate the wound as little as possible.

The beginner must learn gradually, by experience, all that I have mentioned; what he can learn from books is not sufficient. When the operation is finished, the fate of the patient is practically already settled.

§ 21. **The Accidents during an Operation.**—The accidents which are liable to occur during an operation can be only briefly mentioned here. We naturally leave out of account all the numerous unpleasant things which may be caused by the operator's error in diagnosis, his lack of skill and judgment, etc. The reader is referred to my text-book on Regional Surgery for many common accidents peculiar to certain operations—such as the disturbances which may be caused by operations on the mouth, air-passages, and thoracic and peritoneal cavities.

Mention has been made on pages 29 and 41 of the accidents occurring during narcosis. I shall describe the other unfortunate occurrences briefly as follows:

Syncope.—Syncope occasionally takes place, especially in weak and anæmic individuals, during small operations performed without an anæsthetic. It either comes on suddenly, without warning, or it is preceded by a feeling of anxiety, or a sinking feeling about the pit of the stomach, or nausea, etc. The face becomes deadly pale and covered with a cold sweat, consciousness is lost, and the patient falls to the floor

if standing, or drops to one side if he is sitting in a chair. Sudd death has been known to occur in this way, as mentioned on page : During the swoon the sense of pain is lost.

Convulsions.—Hysterical or alcoholic individuals sometimes ha convulsions either with or without the syncope. If the cause of t syncope is purely nervous the patient soon recovers, usually after few seconds, and seldom requires longer than two or three minut If excessive loss of blood is the cause of the syncope the prognosis of course less favourable. The nature and treatment of this form syncope will be taken up under the subject of Wounds.

The treatment of the nervous syncope, if I may call it such, co sists in placing the patient in the horizontal position, sprinkling t face with cold water, chafing and rubbing the body and soles of th feet with wet cloths, giving stimulants, camphor, wine, ammonia, als plenty of fresh air, etc.

Bleeding.—The dangers which arise from bleeding during a operation are slight, as the capable and careful surgeon is able to con trol it in a great many ways. The treatment of bleeding is discusse in §§ 27–30.

An operation may be complicated in a very dangerous way if i is undertaken on an individual of the class of so-called bleeders.

The "Bleeder Disease," or Hæmophilia.—The term "bleeder disease," o hæmophilia, is understood to mean a constitutional anomaly, almost alway congenital, which is characterised by a very marked predisposition to bleeding spontaneously or as the result of some slight traumatism.

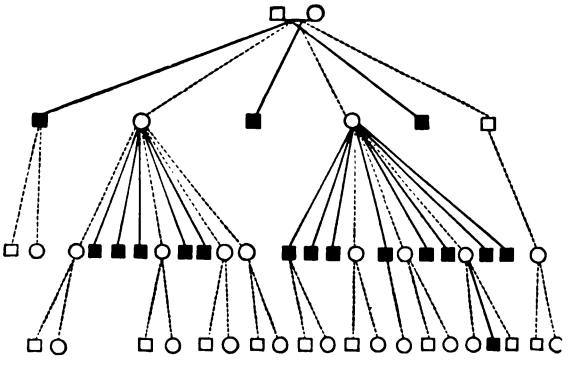


Fig. 46.—Family tree (Lossen). ■, Bleeders (all males); □, healthy males; ○, healthy females.

Hæmophilia is generally an inherited disease, and occurs in so-called bleeder families, in which it is transmitted through many generations, afflicting the members in both the direct and indirect lines of descent. Lossen has investigated three generations of a bleeder family of one hundred members which took its origin from healthy parents; seventeen of this family were bleeders, and nine died from excessive loss of blood (see Fig. 46). The disease appears to be more common in the male sex—according to König, in the proportion of one woman to thirteen men. Furthermore, it is

a fact that hæmophilia is transmitted chiefly through the female members of the bleeder family who do not themselves suffer from the disease and who marry healthy men. Moreover, the children of a male hæmophiliac are usually free from the disease. In only exceptional cases this anomaly appears not to be congenital but to develop slowly after birth.

The pathology of hæmophilia is still but little understood. The cause of the disease has been ascribed to an abnormal thinness of the walls of the vessels, leading to their easy rupture; to their possessing too slight a power of contraction, or rather to a deficiency in the muscular coat of the arteries; to an abnormal blood pressure due to too small a calibre in the main arterial trunks; and, finally, to an abnormality in the composition of the blood, manifested by imperfect coagulation. But there is no proof that any of these causes actually produce hæmophilia, and the microscopical and chemical examination of the blood has hitherto warranted no conclusion as to the etiology of the disease. The blood usually coagulates normally, though I can affirm, in respect to one case at least, that the blood coagulated rather slowly and imperfectly. Manteuffel also found in one case that the blood, without the addition of Schmidt's ferments, required four and a half minutes for coagulation, and with the ferments only ten seconds. I am inclined to believe that the composition of the blood or, in other words, its mode of coagulation is not normal in hæmophilia.

We know that in pronounced leucæmia, a disease of the blood characterised by the presence of an excess of white blood-corpuscles, severe or unrestrainable hæmorrhage may occur. For this reason surgeons hesitate before removing an enlarged spleen in leucæmia; almost all the patients hitherto operated upon have died from hæmorrhage. The walls of the blood-vessels in a case of hæmophilia probably do not possess the normal degree of strength, and consequently are easily ruptured by the slightest traumatism, or even without any known cause.

As to the *symptomatology* of hæmophilia, the hæmorrhages sometimes begin immediately after birth—for instance, as an umbilical hæmorrhage—or they accompany circumcision in Jewish boys; but usually they make their appearance later, at the time of dentition, of shedding the milk teeth, or at the age of puberty; in other words, at periods of life when traumatisms are of more frequent occurrence.

The hæmorrhages, usually parenchymatous in nature, take their origin from traumatisms even of the most insignificant kind. Spontaneous hæmorrhages have been observed without any apparent cause; for instance, in and under the skin and mucous membranes, or from the stomach, intestine, and genito-urinary tract. But these hæmorrhages may be caused by slight injuries of an unknown nature. At any rate, parenchymatous hæmorrhages in internal organs which are thoroughly protected almost never occur.

The traumatisms which produce bleeding in hæmophilia are often of the most insignificant kind; for instance, a trifling pressure on some part of the skin will occasion bleeding into and beneath this area; brushing the teeth will cause the gums to bleed; and blowing the nose is often followed by a prolonged nosebleed. Of especial interest are the hæmorrhages into the joints, producing a peculiar multiple joint disorder (see Diseases of Joints). The bite of a leech or an insect, the prick of a needle, are not uncommonly

followed by a remarkably profuse hæmorrhage. Fatal hæmorrhage h been observed to follow the extraction of a tooth, and when open woun are made and operations are undertaken the result can be imagined. In pronounced case of hæmophilia every method of hæmostasis may be tried vain and the patient will die of hæmorrhage. The bleeding may appear be stopped, but it will recur again and again. Such a state may go on f days, weeks, and even months, but it generally requires only a few days terminate life.

Usually, bleeders seem to possess a remarkable power of withstanding tl loss of blood, and not infrequently recover completely from very large hæn orrhages. One patient of Coates's lost twelve kilogrammes of blood in eleve days. As the subject of hæmophilia grows older the intensity of his disea seems to diminish, and in a few instances it has disappeared entirely.

The prognosis of hæmophilia depends upon the severity of the diseas and the number and kind of traumatisms the individual may be subject t Many sad cases go to show that patients with marked hæmophilia often d not get beyond the age of boyhood, but die quite young from some triflin wound or some necessary operation, or they waste away with marked ana mia, which is gradually produced by the constantly recurring losses of bloo resulting from the slightest mechanical injury. As they get on in years th prognosis improves, and the disease, when rudimentary in character, ma disappear altogether.

Treatment of Hæmophilia.—In the case of children who come fron bleeder families or have a marked tendency to bleeding, prophylaxis is ver important. Every means should be taken to improve their general conditio by good food and air, by frequent baths, by a careful toughening of the body etc., and in this way the disposition to bleeding may perhaps be checked, o at least diminished. The rest of the prophylactic treatment consists in protecting the patient, as far as possible, from every kind of traumatism which may give rise to bleeding. Any trifling mechanical or operative procedure —for instance, vaccination—should be conducted with the utmost caution operations should only be performed in case of the most extreme urgency. Not infrequently bleeders have died of hæmorrhage after an operation, because there was no previous knowledge of their fatal peculiarity.

The process of healing in bleeders is accompanied by peculiar difficulties, which are illustrated by an experience of Thiersch's, who removed an encysted tumour from the face of a bleeder at his urgent request. The wound took six weeks to heal, and the patient came near dying from the complications. Thiersch recommends, from his experience, that the wound be not sutured, and that compression dressings be discarded.

Hæmorrhage in bleeders is checked by ligation of the bleeding vessels, and when necessary by the application of a solution of perchloride of iron, or the actual cautery, generally in the shape of the Paquelin instrument. It has been mentioned that bleeding is especially apt to occur when the eschar or thrombus comes away, and therefore it should be kept from being disturbed as long as possible. Thiersch, in his case, allowed the wound to fill with a blood clot and surrounded it with a wall of compresses impregnated with ten-per-cent. salicylic acid, and then wrapped the whole in a thick layer of carbolised jute contained in sterilised gauze without applying any pres-

sure. In this way he avoided all pressure, and also prevented the clot from becoming prematurely loosened. On the thirty-eighth day the clot came away and the entire surface of the wound was skinned over.

Manteuffel stopped the hæmorrhage from an alveolus by cocaine and insertion of a piece of cotton which was saturated alternately with Schmidt's coagulating ferment (zymoplasma) and an aqueous solution of thrombin.

Henry Finch, from a successful experience with three cases, advises venesection in hæmophilia in conjunction with hot-water irrigation. By means of the latter the coagulation of the blood is rendered more rapid and complete. Wright praises the internal administration of the salts of lime prior to operation, these salts, as is well known, increasing the coagulability of the blood (see § 61). The internal treatment of hæmophilia by ergotin, acetate of lead, laxatives (Glauber's salt), etc., is useless.

Entrance of Air into the Veins.—The unpleasant consequences of the entrance of air into the veins should receive special attention. It occurs exclusively after wounds of the veins in the neighbourhood of the thorax, or more particularly of the heart; among these veins are included the axillary, subclavian, jugular, etc. There is scarcely ever a positive pressure in these veins, and with every inspiration it becomes decidedly negative, so that air is sucked in when they are wounded—for instance, during an operation. Added to this, the veins in immediate proximity to the thorax gape open after being wounded, and fail to collapse because they are so closely attached to the surrounding connective tissue and fascia.

This is the case with the superior vena cava, subclavian, and internal jugular veins. Death only takes place when a large amount of air is sucked in at once; but single air bubbles are harmless, as they gradually disappear from the blood. Death from the entrance of air into the veins has been explained in various ways. According to Couty and Jürgensen, the air collects in the right side of the heart and prevents the contraction of the right ventricle, causing the heart to stop finally in diastole. The filling of the right side of the heart prevents the entrance of venous blood, thus stopping first the pulmonary and then the whole arterial circulation. According to others—Passet, for instance—the air passes from the heart to the pulmonary arteries, where it is arrested, interrupting the pulmonary circulation and preventing the left ventricle from filling with fresh blood. According to a third theory, air embolisms in the cerebral arteries furnish the principal cause of death.

Recently Hauer has studied the subject, experimenting chiefly on rabbits, and has come to the conclusion that death is principally the result of air embolism in the small pulmonary vessels, and that death can likewise be caused by emboli in the cerebral vessels, as small air bubbles pass through the pulmonary circulation into the left ventricle. The introduction of air into the veins has long been made use of as a method of producing death experimentally in animals. Rabbits are very sensitive to air in the veins, while in dogs eight to ten cubic centimetres of air can be injected into the central end of the jugular vein without a fatal result.

In man, the aspiration of air into the veins has hitherto been observed to occur principally during operations in the neighbourhood of the thorax (*région dangereuse*). Greene has collected sixty-seven cases with twenty-

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seven recoveries, but a large proportion of these are untrustworthy. The air is generally aspirated with an audible sucking, gurgling sound, and in the worst cases death occurs immediately. If the amount of air taken in is small, the patient will recover, though König saw in such a case great anxiety, with laboured breathing and dilated pupils.

Besides the veins just mentioned, wounds of other veins have been known to result fatally from aspiration of air, particularly after a very deep inspiration. This is true, for example, of the dural sinuses and of the veins at the bend of the elbow during venesection. Aspiration of air is not possible in the case of the veins of the lower extremity. Spontaneous aspiration of air must not be confused with injection of the same, as, for example, in uterine injections. Injection of air into the veins of the uterus may also prove fatal.

Treatment of Air in the Veins.—Our treatment of this condition amounts to very little. By way of prophylaxis, operations in the neighbourhood of the great veins, particularly in the neck, should be conducted with the greatest care. If a large vein is wounded and air is sucked in, the opening in the vein should be immediately stopped with the finger, especially during inspiration, and the wound filled with an aseptic fluid, perhaps squeezed from a sponge, as air only gets into the vessel when the wound is dry. Sometimes the air bubbles are forced out of the open vein during expiration, and on this account Fischer has suggested that vigorous expiratory movements be made by compressing the thorax. The vein is then to be ligated as quickly as possible to prevent any further entrance of air. If the amount of air that has entered the vascular system is not too great it can be rapidly absorbed or eliminated. The air is eliminated, according to Heller, more quickly if the patient inhales a mixture of air containing very little nitrogen. If a large amount of air has already been sucked into the vein and has reached the heart, further treatment is, of course, useless, for death in such cases is usually instantaneous.

Other Causes of Death during an Operation.—These, aside from the cases of actual malpractice, are usually due to the large amount of blood lost; to the particular kind of operation and the length of time it takes; to the excessive loss of body heat, especially in operations in the peritoneal cavity; and, finally, to the constitution of the patient. These subjects are fully discussed in another chapter.

§ 22. **The Post-operative Treatment of Patients.**—The student is referred to the Regional Surgery for the after-treatment of special operative cases.

The general treatment of the patient is very simple if, as usually happens, the healing process runs a normal course. After the operation has been performed and the dressing applied, the patient is put to bed and surrounded, when necessary, with warm bottles, not too hot, which are usually wrapped in flannel to prevent them from burning the skin. The position of the patient should be as comfortable as possible, with especial reference to the part of the body which has been

operated upon. Old people, those suffering from emphysema, etc., should not have their head and thorax placed too low, as dyspnœa or a hypostatic congestion of the lungs may easily occur. Immediately after the operation the symptoms which are the result of the narcosis become more or less prominent. For their treatment, see page 36.

It is very important to take the temperature two or three times a day with a reliable thermometer, and also to keep run of the pulse. Recovery usually takes place without fever, the latter being the result either of imperfect asepsis during the operation or of a fever existing before the operation. Every wound fever is caused by the absorption of toxic substances from the wound into the general circulation. The so-called aseptic wound fever (Volkmann, Genzmer), which probably depends upon the absorption of blood or fibrin ferment, is but seldom seen. In general, it has been my experience that in all cases where fever follows operation there will be found a corresponding disturbance of the normal course in the healing of the wound. For the details of the nature and treatment of this fever, see § 62.

The greatest pains, therefore, must be expended on a careful supervision of the healing process. The dressings should be changed if it is called for on account of fever, pain, or for the removal of drainage, stitches, etc., or if the dressings become loosened, displaced, or saturated by the secretion from the wound. The diet should be reduced in quantity, since the need of nourishment is less because of the rest in bed and the lack of exercise. Weak individuals should be given plenty of wine and light, easily digestible, but strengthening food. For quieting the patient or for allaying pain, morphine should be administered in the form of a subcutaneous injection (0.01 to 0.02 gramme). But morphine must be used with caution; while some individuals can take very large doses with impunity, others will manifest symptoms of poisoning after very small doses. Next to morphine, the best hypnotic is chloral hydrate (Liebreich), two to three to five grammes of which, given in a glass of water, will usually induce sleep very quickly. But patients soon get used to the drug, and it then becomes more or less ineffectual and may produce gastric irritation. Of the new hypnotics, sulphonal and paraldehyde are very good.

§ 23. **The Most Important Causes of Death after Operation** are briefly as follows: Collapse; shock; anæmia; secondary hæmorrhage; poisoning from the drugs used with the dressings, such as iodoform, carbolic acid, bichloride of mercury, etc.; and particularly the wound diseases which come from infection with micro-organisms—erysipelas, pyæmia, and septicæmia, which will be described in their proper places.

We aim to prevent the infectious diseases by the most rigid asepsi during the operation; to prevent poisoning by the cautious use o antiseptics, and secondary hæmorrhage by the most careful ligatio of bleeding points in the wound. We try to make the amount o blood lost during the operation as small as possible by the method described in § 18 and § 19. The best means to prevent an impending collapse from hæmorrhage is the transfusion of defibrinated blood or, better still, of a 0.6-per-cent. solution of sodium chloride into the circulation or subcutaneously.

Recent experiments have demonstrated that the infusion of a 0.6-per-cent. solution of sodium chloride into the general circulation is, on the whole, better than transfusion of blood. (For particulars, see § 89.) Patients suffering from acute anæmia should also be given plenty to drink, and wine especially. If collapse comes on, subcutaneous injections of camphor (1 to 5 of olive oil) and ether should be given with the hypodermic syringe. In severe cases this hypodermic administration of camphor and ether may be repeated several times at intervals of a few minutes.

Neuroses following Operation.—Sometimes after operations neuroses of the most varied sort will occur, especially hysterical phenomena, melancholia, nervous delirium, etc. They are most common in neurasthenic subjects, and repeated narcoses may increase their severity to a marked degree.

The Influence of Constitutional Anomalies on the Healing of the Wound.—Emphasis has justly been laid upon the fact that the wound will run the normal course in healing if the operation has been performed with the most rigid observance of asepsis.

But there are chronic diseases, constitutional derangements in the nutrition of the tissues, which occasionally influence the course of healing in the wound (Verneuil, Paget). To this class belong especially chronic endarteritis, gout, alcoholism, syphilis, Bright's disease, diabetes, scurvy, malaria, leucæmia, pernicious anæmia, the morphine habit, etc.

Individuals suffering from chronic heart or kidney disease generally have little power of resistance, and not infrequently collapse after a slight and insignificant operation. As Lloyd has remarked, disease of the kidney can be so intensified by ether or chloroform narcosis that threatening symptoms of a collapselike nature may make their appearance. These chronic diseases will sometimes cause a great retardation in the healing of the wound made during the operation. It is well known how badly wounds heal in persons afflicted with scurvy, leucæmia, pernicious anæmia, and diabetes. Operations should be carried out with every antiseptic precaution in the case of pregnant women; while in children less than a year old, as well as in the very aged, great care must be taken to prevent unnecessary loss of blood.

3. Lancet (Fig. 47, *h*). This form of knife is old-fashioned, a is but little used at present, except the so-called vaccination lancet (F 47, *i*). Its point has a shallow groove for carrying lym or vaccine virus.

Fig. 48.—Blunt-pointed bistoury.

As shown in the illustrations, the blades of the scal and bistoury have different shapes, some being decide or slightly convex, or straight or curved to a greater less degree. The tips of the blades are also differe some being pointed (Fig. 47, *a–e*) and others blunt (Fi 47, *f*, and 48). Many knives are double-edged or lan shaped (Fig. 47, *e*). We use the blunt-pointed knife those cases in which we wish to avoid injury to the joining tissues by the point of the knife. The leng and breadth of the blade vary with the kind of operati in which it is intended to be used, the strongest, longe and broadest knives being for amputations, disarticulations, and joi resections. For particular operations there are especially design

Fig. 49.—Penholder method of using the knife.

Fig. 50.—Fiddle-stick method of holding the knife.

knives. The handle of the knife is of wood, horn, ivory, steel, gla etc., and the end is usually made like a chisel, to facilitate teari through the tissues when necessary. A nickel-plated metal handle best adapted for the necessary sterilisation of the knife by boiling in a one-per-cent. soda solution.

The usual ways of holding the knife are illustrated in Figs. 49–54, but I do not lay down strict rules when to use this or that method. No regular rules are needed by any one having a natural

Fig. 51.—Method of holding a large knife (resection knife).

Fig. 52.—Method of ho ing the knife when tissues are divided fr within outwards.

aptitude for operating, or by any one who is familiar with dissectic Large knives, like those used for resection, are held as pictured

Fig. 51. The amputation knife is grasped in the closed fist, as in Fig. 53. On the other hand, the lancet is held as indicated in Fig. 54.

The skin is usually divided as follows: After making the skin tense by the thumb, index, and middle fingers, the incision is begun by the scalpel, held in the right hand, as shown in Figs. 49, 50, or 51, and the blade is drawn between the above-named fingers. Or a fold of skin is lifted up at right angles to the direction of the intended incision, which is then carried down through the fold. If it is desired to make a long incision at one stroke, the knife should be drawn rapidly along without applying much pressure.

Fig. 53.—Method of holding a large amputation knife.

Fig. 54.—Method of holding the lancet.

We frequently cut from within outwards, as in the division of a fistulous tract, when the knife is held as in Fig. 53. For this purpose grooved probes or directors are commonly used (Fig. 55). In many operations, as we shall see, this director is indispensable, and it is especially valuable for the beginner. In such cases the director is pushed under the particular layer of tissue, or into the fistulous opening, and the point of the knife, cutting edge upwards, is pushed along in the groove, thus dividing the tissues. The cutting can be done from in front backwards, or *vice versa*, according to the case in hand. In conclusion, mention should be made here of the ear, myrtle-leaf, and rounded end probes (Fig. 56, *a*, *b*, *c*). These probes are generally used for diagnostic purposes, such as exploring fistulous tracts in soft parts and bones, in the search for foreign bodies, such as sequestra, etc. Probes made of silver, so that they can be bent, are the best. Before use,

Fig. 55. Grooved directors. Fig. 56. Probes. Fig. 57. Tenotome.

every probe should be disinfected as carefully as possible. There will be opportunity enough for warning against too much probing of tis-

FIG. 58.—Toothed forceps.

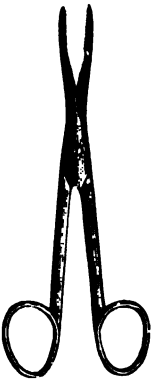

FIG. 59.—Dressing forceps.

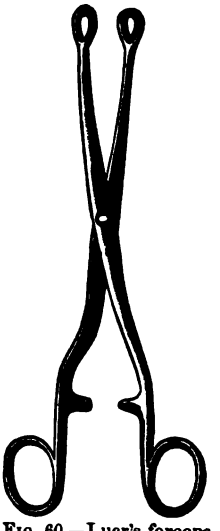

FIG. 60.—Luer's forceps with a clasp on the handles.

sues, but it is worth while to give a general caution on this subject now. In searching for foreign bodies the magnetic needle has been frequently used with success (Kocher, Kälin, Lauenstein, Graser, and others).

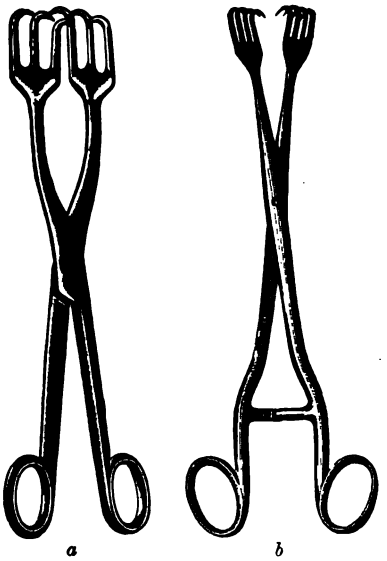

FIG. 61.—Muzeux's toothed forceps: *a*, without; *b*, with a clasp on the handles.

Mention should be made of the subcutaneous incisions which are employed for such cases as the division of contracted tendons, club-foot, etc. The so-called "tenotomy knife" is used for this purpose; it is a small, sharp-pointed knife with a curved blade and a stout handle (Fig. 57). With this knife the skin is punctured, and the tendon is divided beneath the skin without cutting through the latter.

For holding and retracting the tissues after division of the integument we use particular instruments, especially the surgical thumb forceps, clamps, and hooks. Surgical thumb forceps differ from the ana-

tomical kind in having two to four small teeth at the end of the blade, to enable them to get a better hold on the tissues. Hooked thumb forceps (Fig. 58, *b*), fitted with rather long, curved hooks, are excellent for certain purposes, such as seizing small cutaneous tumours. The larger hooked thumb forceps of this kind can be closed and locked by a spring (Fig. 60). There are numerous other kinds of forceps for grasping the tissues, sharp and blunt, and of various shapes for the particular kind of operation in which they are intended to be used. Among the blunt-bladed variety are the sequestrum or dressing forceps (Fig. 59), straight and bent, and Luer's forceps, which have on the handles a self-locking ratchet to keep them closed. Another kind

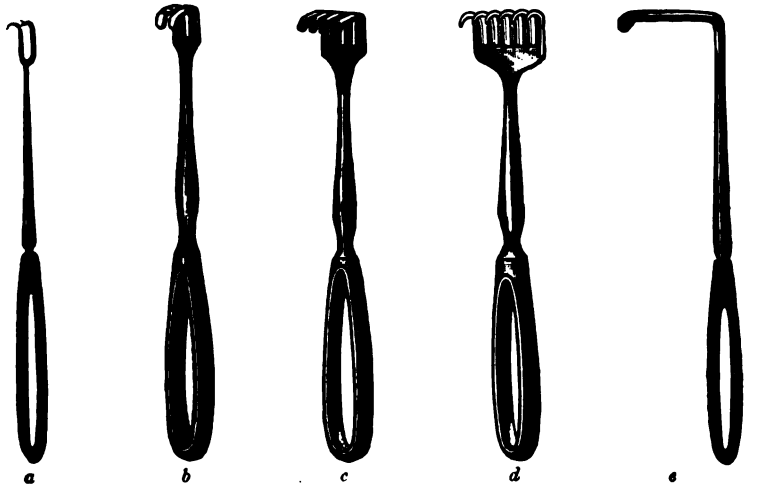

Fig. 62.—Retractors (sharp and blunt).

is the well-known forceps of Muzeux, which are straight or bent, and are provided with hooks (Fig. 61, *a*, *b*). These hooked forceps have from two to eight or more curved, sharp hooks on the end of the blades.

For making counter openings quickly and without loss of blood, Wölfler uses a cutting sequestrum forceps, which is made with one blade prolonged into a lance-shaped point, so that it can either be protruded beyond the other blade of the forceps (unsheathed perforating forceps), or by withdrawing the sharpened blade the latter is easily covered (producing the sheathed perforating forceps). The sheathed forceps is suited for those cases in which, to make a counter opening, a considerable mass of soft parts must be traversed, as in compound fracture, extensive phlegmonous processes, for making counter openings at the bottom of the true pelvis, etc.

After making the skin incision the margins of the wound are held apart by blunt or sharp hooks, to enable the operator to obtain a better

view of the deeper-lying parts or to divide them. Retractors (Figs. 62 and 63) are either simple blunt hooks, like an aneurism needle used in tying a vessel, or an ordinary sharp hook with one or more tines, or a blunt hook bent at a right angle. In case of emergency a retractor can be made out of pliable wire (Fig. 64). Self-retaining retractors are also in use.

The scissors commonly used are straight or curved on the flat, or they have an angular bend. The various kinds of scissors designed for particular operations are described in Regional Surgery. The scissors are held for operating in the way we have learned to handle them in anatomical practice. I frequently give the preference to scissors, especially in the removal of tumours, as they facilitate rapidity in operating.

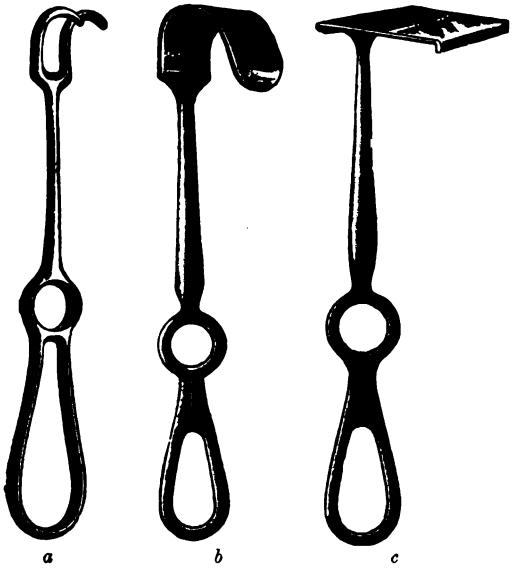

FIG. 63.—Large blunt retractors, chiefly for abdominal operations.

FIG. 64.—Improvised retractor made of pliable wire.

Puncture of the soft parts can be done with a pointed knife, or a trocar or hollow needle, for the evacuation of fluid—e. g., from the pleural or peritoneal cavities, or from the scrotum; or for diagnostic purposes, to determine the nature of the contents of a cavity, or the nature or a tumour; or, finally, to introduce fluid medication into the tissues or general system.

A trocar (Fig. 65) consists of two parts, a stylet or trocar with a handle, and a tube or cannula enclosing the stylet. The cannula is provided with a metal shield at its posterior extremity. Trocars are straight or curved, the latter, for instance, being used for puncture of the bladder above the symphysis pubis in case of retention of urine. The calibre of the trocar varies with the uses to which it is intended to be put, the smaller sizes having the advantage that they cause only a small puncture, and the disadvantage that

they take a long time to evacuate the fluid; and if the cavity contains a thick fluid, perhaps mixed with flakes of fibrin, the liquid may finally cease flowing from obstruction in the cannula. The method of holding the trocar for making a puncture is illustrated in Fig. 66. After it has been introduced far enough, the shield of the cannula is grasped by the left hand, the stylet or trocar is withdrawn, and the fluid then escapes through the cannula, which is left in place. Before using, the trocar and cannula must always be boiled for five to ten minutes in a one-per-cent. soda solution. In former times, before these precautions were taken, and when neither the skin area in question nor the instrument was disinfected, this trifling operation was sometimes accompanied by infection of the albuminous contents of the cavity, with ensuing septic inflammation. To prevent the entrance of air—for instance into the pleural cavity, Fergusson, Fraentzel, and others have fitted the trocar with a certain contrivance which will be described in the text-book on Regional Surgery (Puncture of the Pleura).

Fig. 65. Trocar.

Fig. 66.—Method of holding the trocar in making a puncture.

For diagnostic purposes, the exploratory puncture is made with a very fine trocar, or, better still, with an aspirating needle (Fig. 69) having a tight-fitting piston and joints. After inserting the hollow needle of the syringe, the graduated piston-rod is slowly withdrawn, thus causing the fluid contents of a cavity to flow into the barrel of the syringe.

For aspiration of the contents of a cavity, Dieulafoy, Potain, and others have made a suitable apparatus and have introduced it into general use. Syringes have also been constructed on the plan of Weiss's stomach pump for siphoning off or pumping out fluid from some part of the body. An aspirating apparatus similar to Potain's (Fig. 68) or Alexander's (see next page) can be easily made from a bottle with a rubber cork and two glass tubes.

Fig. 67.—Dieulafoy's aspirator.

Dieulafoy's Aspirator (Fig. 67) consists of a cylinder with a capacity of forty-five to fifty grammes, fitted with a graduated piston-rod which is notched at *A*, and, after being withdrawn, can be held fast at *B*. At *C* and *D* are two stop-cocks, which can be opened or closed, and the hollow needle is connected with the syringe by a rubber tube. Before puncturing with the needle it is best to withdraw the piston and form a vacuum in the barrel of the syringe, so that during the operation there can be no disturbing of the needle with tearing of the tissues. Both stop-cocks *C* and *D* are closed; the piston is withdrawn and retained at *B* by turning it slightly from

left to right. The cavity of the cylinder is now relatively a vacuum. The upper end of the rubber tube is then fitted on the stop-cock at the end of the cylinder, while the hollow needle attached to the other end of the tube is plunged into the cavity in the body which it is desired to empty. The stop-cock *C* is opened and the liquid flows into the cylinder. To empty the cylinder of the liquid, the cock *C* is closed and *D* is opened, and by pushing down the piston the liquid flows out of *D*. If necessary, this can be repeated one or more times. Aspiration can also be practised by thrusting the needle into the tissues first, and then, after closing the cock *D*, opening *C*, and by withdrawing the piston the fluid is allowed to flow into the syringe.

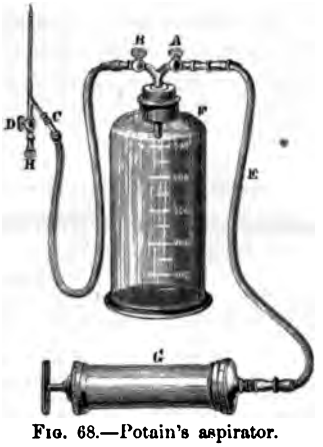

Fig. 68.—Potain's aspirator.

Potain's Aspirator (Fig. 68) consists of a graduated glass flask *F*, which is closed by a rubber stopper, and has a capacity of five hundred grammes. The rubber stopper is pierced by a metal tube divided into two compartments, one communicating with *A*, the other with *B*. One rubber tube *E* goes to the pump *G*; the other, which is fitted with a glass tube *C* to enable the liquid to be seen as it passes, is fastened to the lateral portion of the cannula of a trocar. The cannula is fitted with a stop-cock *D*. This apparatus is used in the following way: The cock *B* is closed, *A* is opened, and a vacuum is made in the flask by means of the pump *G*; then *A* is closed, and the puncture is made with the trocar. The stylet *H* is then pulled out, and the cannula is closed by the cock *D*, while *B* is opened, thus allowing the liquid to flow out through the cannula, glass and rubber tubes into the glass vessel. During the aspiration the suction can be increased by opening the cock *A* and working the pump *G*. Alexander's apparatus is similar to Potain's. In place of the pump *G* there is a pear-shaped rubber bulb which acts as a suction or pressure pump, depending upon whether it is attached to the rubber tube. The new aspirator invented by Debove, in which all stop-cocks are done away with, is a most excellent instrument. By a quarter turn of the handle the lateral openings of the cannula and trocar can be made to correspond, and thus allow the fluid to escape. The apparatus can be easily cleaned (Illustr. Monatssch. der ärzt. Polytech., June, 1889; this also contains a description of the automatic aspirator of Ruault).

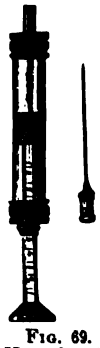
Fig. 69. Hypodermi syringe.

Finally, we often puncture the tissues with a hypodermic needle or a similar instrument to introduce morphine, cocaine, ether, camphor, mercury, etc., into the neighbouring tissues or the general system. The hypodermic syringe usually contains one gramme, and the piston-rod is suitably marked off to permit an accurate measurement of th amount of medicament administered. After filling the barrel of th

syringe with the fluid to be used, the hollow needle, having been carefully disinfected, is put in place, and the air is driven out of the syringe by holding the point upwards and gently pushing on the piston. To make the injection, a fold of skin is pinched up, the needle is plunged into the subcutaneous tissue, the syringe is emptied, the fold of skin is released, the needle is withdrawn, the tip of the left index finger is placed upon the point of puncture, and the injected fluid is evenly distributed by gently rubbing the area with the index and middle fingers.

For making parenchymatous injections (that is, injections of medicated fluids into organs—e. g., muscles, glands, joints, etc.) it is customary to introduce the fluid at more than one point, particularly if large amounts of a medicament are to be administered.

The Care of a Hypodermic Needle.—To keep a hypodermic needle in a serviceable state, it should be washed out with water after use, and the traces of fluid should be blown out of the needle—or, better, dried out by heating the needle in a spirit lamp. This prevents the needle from rusting, keeps it from becoming stopped up, and makes it unnecessary to introduce a silver wire for rendering the needle pervious. To prevent the piston from drying and to keep it tight, it is worth while to introduce a drop of oil occasionally between the leather washers.

The small punctured wound made by the trocar or hollow needle can be covered with iodoform-collodion (one part iodoform, ten parts collodion), or with a bismuth and bichloride-of-mercury solution; only exceptionally would an antiseptic dressing be necessary.

Fig. 70.—Volkmann spoons, *a* and *b*; *c*, open scraper.

Chronically inflamed tissues, and more particularly those which have undergone caseous degeneration, are removed by scooping and scraping them out with sharp spoons (Fig. 70). The operation is called "scraping out" (sinuses, fistulæ, etc.). Sharp spoons are straight or slightly bent, and of different sizes. The open raspatory (Fig. 70, *c*), unlike the sharp spoon, has two sharp edges.

§ 25. **Bloodless Division of the Tissues by Tearing, Twisting, etc.**—Under this heading comes, in the first place, the division of the tissues, especially the loose connective tissue, by means of the tips of the fingers, the handle of the scalpel or the director, thumb forceps, clamps, etc.; then the tearing out, or twisting off, or squeezing off of small

tumours—for instance, from the larynx or the nose—by the use of cial forceps. In all such cases the bleeding is so slight that the o tion can in fact be called more or less bloodless. All large wo produced by blunt instruments bleed but little, because the vessel twisted and squeezed together in the process.

The Division of the Tissues by the Ligature, or Strangulation, is an quated method of operating; it is too slow, it is painful, and not infrequ gives origin to inflammatory and even dangerous suppurative proc The technique of its use is briefly as follows: The particular part in tion—for example, a pedunculated tumour, a hæmorrhoidal protrusion —is tightly encircled about its base by a strong silk ligature or elastic l less frequently by a strand of silver wire, and thus gradually death o part takes place. The elastic ligature is best secured by passing its kept at a proper tension, through a lead ring, the sides of which are pinched together by a pair of nippers. The silver ligature is applied, and then retained by twistin ends around each other.

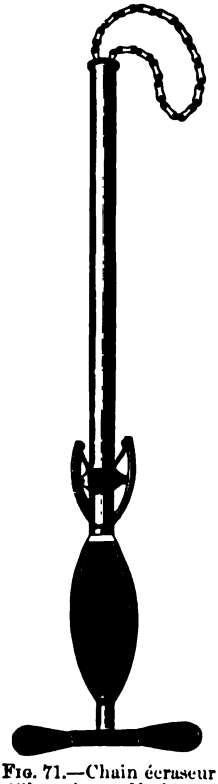

Fig. 71.—Chain écraseur (Chassaignac-Mathieu).

Écrasement.—*Écrasement linéaire*, as it is call Chassaignac, who devised and introduced it, is also a form of division of tissues by ligature. The tissues are divided, or rather compressed, and thus necrosis takes place at the line of pressure (Fig. 71). The chain of Chassaignac's écraseur is like a chain-saw without teeth, and is made to encompass the portion of tissue to be removed, or is passed through a fistulous tract by a probe, or is carried through the parenchyma of an organ by a needle, and so around part of the organ, as in grasping a portion of the tongue. In the two latter instances the chain of the écraseur is first applied and then laid in the shank of the instrument. By means of the thumb-screw at the handle end of the instrument the chain ligature can be shortened—that is, the portion of the tissue in the grasp of the chain is gradually cut through by pressure necrosis. Similar instruments have been brought forward by Luer and Charrière. The wire écraseur of Maisonneuve is fitted with a wire instead of a chain; by turning the thumb-screw at the h of the instrument, the loop of the wire ligature is made smaller. Chassa and Maisonneuve have tried in vain to introduce écrasement more w

Fig. 72.—Wir seur (Maisonr

into operative surgery, urging as advantages of their method the absence of hæmorrhage, and particularly the diminished chances of the absorption of septic matter, as the lymphatics and connective-tissue spaces are more or less closed by pressure. But these statements are exaggerated, since, in the first place, there is no certainty that the écraseur, as it cuts its way through, will not cause hæmorrhage, especially from medium-sized arteries. Quite recently Doyen has modified écrasement by his "angiotripsy." This consists in crushing or dividing tissues in different operations, such as those on the stomach, intestine, uterus, etc., with special forceps. Any vessels are, if necessary, ligated. Tuffier went a step further. He closes the vessels by compression with a specially constructed forceps without ligating the vessel before or afterwards. He reported twenty-three cases of vaginal hysterectomy which he performed with his angiotribe without ligatures and artery clamps.

French gynæcologists have recently recommended the use of long clamps in place of ligatures in performing vaginal hysterectomy. The clamps remain in position from two to four days. If they are removed too soon, serious secondary hæmorrhage may take place. This method is to be recommended in suitable cases on account of its simplicity.

The Cautery—the Paquelin Thermo-cautery.—The division of the tissues by the cautery (red-hot iron) is a very ancient method, and in the middle ages was used especially by the Arabian physicians. The

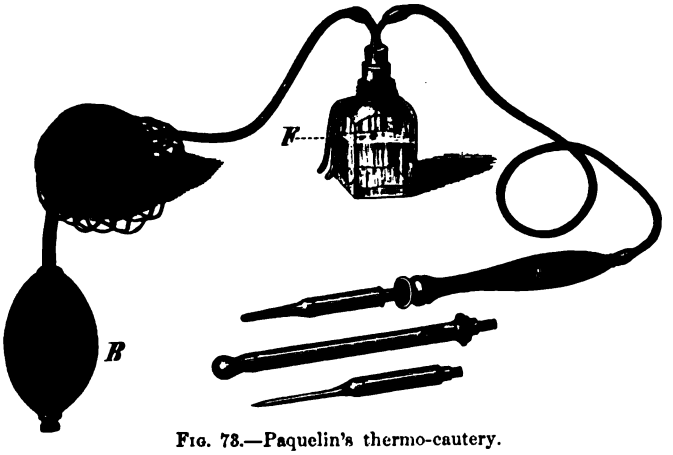

Fig. 73.—Paquelin's thermo-cautery.

ordinary cautery is made of different-shaped iron or brass rods with a wooden handle, and was formerly heated red-hot among glowing coals; but now it is usually heated in the flame of a Bunsen burner or a spirit lamp.

The old-fashioned cautery is at present entirely supplanted by Paquelin's thermo-cautery (Fig. 73). Every physician should possess one of these instruments. The apparatus works on the principle that

platinum, after being sufficiently heated in the flame of a spirit lamp will be made red-hot by the ignition, in the already hot platinum, of a mixture of air and vapour of petroleum ether (hydrocarbon compounds). In this process the petroleum ether is decomposed into water and carbonic acid, thus giving rise to so much heat that the platinum becomes red-hot. Paquelin's apparatus (Fig. 73) consists of a glass bottle half filled with petroleum ether (*F*). I use a mixture of two parts of benzine and one part of petroleum. The impure benzine is better than that which is chemically pure. By squeezing the rubber bag *B*, the vapour of petroleum ether is driven out of the bottle through the rubber tube and through the hollow interior of the instrument into the hollow space inside the platinum tip. The thermo-cautery is managed very simply: The point of the instrument is heated in the flame of a spirit lamp for a couple of minutes, or long enough to reach a red heat, and then, by squeezing the rubber bag, the benzine petroleum vapour is driven out of the bottle into the platinum of the instrument, where it becomes ignited. In this way a very excellent cautery is prepared, capable of very powerful action. The most useful tips are those with bulbous and knife shaped extremities, like the so-called fistula cautery tip illustrated in Fig. 73. Platinum scissors the blades of which can be made red-hot are not useful and can always be dispensed with. The Paquelin thermo-cautery is in many respects better than the galvano-cautery, which will next be described; but the latter has the great advantage that it can be introduced cold—for example, into the nasal, oral, or pharyngeal cavity—and at any moment, by closing or opening the circuit, it can be brought to a red heat. The advantage of the Paquelin lies in its simplicity and cheapness. Paquelin has recently perfected his cautery so that it can be put to various uses, and can be employed in mineralogy, chemistry, bacteriology, etc.

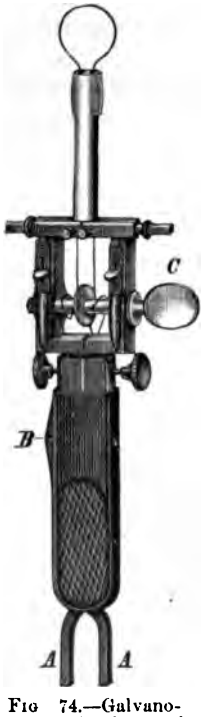

Fig. 74.—Galvano-caustic loop of platinum wire.

As a substitute for the Paquelin cautery Déchery has recommended the aphyso-thermo-cautery ("aphyso-cautère"), which after previous warming with ether comes to a red heat of itself.

Galvano-cautery.—The galvano-cautery was brought into general use by Middeldorpf. The most important instrument is the galvano cautery made of a platinum wire loop (Fig. 74), which is tightened by

turning the ivory thumb-screw *C*. At *A A* the instrument is connected with a battery by two conducting wires, and by closing the circuit the

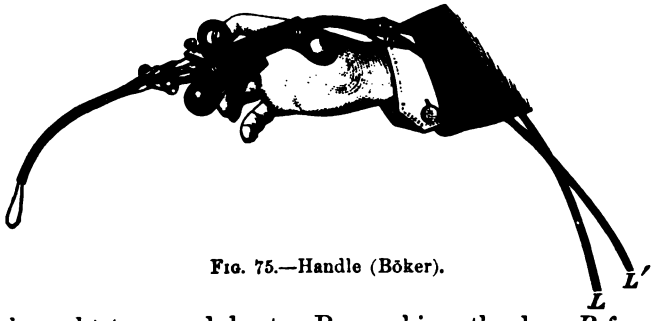

Fig. 75.—Handle (Böker).

wire is brought to a red heat. By pushing the key *B* forwards or backwards, the current is made and broken. Instead of the expensive, frail, and so easily broken platinum wire, Voltolini has recommended the cheaper steel wire (piano wire) for use in the galvano-cautery, and this answers every purpose perfectly.

Fig. 76.—Various galvano-cauteries for the ear, nose, throat, and larynx.

For managing the galvano-cautery loop with one hand, a special handle has been devised; one of the best is that of Bruns, which has been recently improved by Böker (Fig. 75). There are three rings on this handle, for the thumb, index, and middle fingers respectively, the fourth finger being held in the key which breaks and closes the circuit. The ring for the index finger is fastened to the movable cross-piece to which the wire making the loop is attached. By flexing the index finger, the corresponding ring, and with it the cross-bar and attached wire loop, are drawn towards the thumb, thus narrowing the loop. *L L′* represent the two wires connecting the instrument with the battery.

Fig. 77. Porcelain burner.

The other kinds of galvano-cauteries are variously shaped; besides the pointed and straight platinum points, or those which are more or less curved, there are the spatula-shaped, knobbed, conical, or spiral-

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shaped cauteries. By pressing the button *B* on the handle (Fig. 76) the circuit is closed. At *A A* are attached the wires connected with the galvanic battery. The so-called porcelain cautery (Fig. 77) consists of a conical-shaped piece of porcelain with a spiral of platinum wire. As to the battery for working the galvano-cautery, I use exclusively the zinc-carbon-chromic-acid battery of Voltolini (Fig. 78). We shall learn in Regional Surgery the particular cases for which the galvano-cautery is suitable. It should only be mentioned in passing that even major operations—amputations, for example—have been performed by the galvano-cautery loop under exceptional conditions; for instance, to prevent loss of blood when a very high grade of anæmia is already present. Before the days of antisepsis, Hagedorn, by means of his écraseur loop, amputated a leg and a thigh without primary or secondary hæmorrhage, and without applying any ligatures. Bruns has also repeatedly used the galvano-cautery method to perform amputations. At present the galvano-cautery is no longer used for amputations, as they can be performed by the knife with the help of Esmarch's artificial anæmia without loss of blood, and at the same time the wound can be made to heal by primary union in a very short time—a thing which is impossible in the wound made by the galvano-cautery, as is always the case in a wound which is the result of a burn.

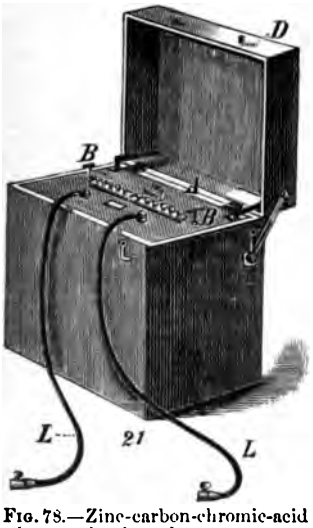


Fig. 78.—Zinc-carbon-chromic-acid battery for the galvano-cautery.

Battery of Voltolini.—Voltolini's zinc-carbon-chromic-acid battery (Fig. 78) contains twenty-one zinc-carbon elements. The latter were originally combined in the so-called "chain"—all the carbon elements connected with each other on one side and all the zinc on the other. As this plan gave but little heating power, Voltolini improved the battery by adding a contrivance (*A*) for combining at will four pairs of elements, and thus succeeded in heating the porcelain cautery-tip red-hot. The fluid used in the battery consists of one part of bichromate of potassium, one part of concentrated (not fuming) sulphuric acid, and ten parts of water.

To fill the battery, the cover of the box is lifted off with the attached elements by seizing the handles (*B B*, Fig. 78), and the glass vessel contained in the box is half filled with the above-described fluid. The elements are then replaced in the box and the connecting wires attached to the battery and the galvano-cautery instrument. After the cover (*D*) of the battery has been put back in its horizontal position, the fluid contained in the glass vessel inside the box surrounds the elements and the battery is ready for use.

If the cover is only half shut, or remains open, as in Fig. 78, the glass vessel is displaced to the bottom of the box, the fluid does not touch the elements, and the battery cannot be used. The cover is retained at any desired angle by means of a rod fastened to it on the outer side of the box. After using the battery the elements are taken out of the box, carefully washed off with water, and dried. The zinc plates must occasionally receive a fresh amalgam of quicksilver; they are taken out of the battery, dipped in dilute sulphuric acid (1 to 7 or 10), and then treated with pure mercury. To bring the mercury more thoroughly into contact with the zinc, it is rubbed into the plates of the latter with a toothbrush or coarse paper.

Battery of Bruns.—The zinc-carbon-chromic-acid battery of Bruns is an excellent apparatus.

Seiler's Battery.—Seiler has also introduced a new form of battery for the galvano-cautery. It consists of zinc-carbon elements in a fluid made of a mixture of sulphuric acid and bichromate of potassium; the elements are immersed in the fluid by turning a crank connected with a pedal. The operator keeps his foot upon this during the operation, and, by exerting more or less pressure with his foot, can regulate the strength of the current. To protect the surrounding parts from injury while the cautery is heated, Seiler has sheathed the part of his cautery instrument not intended to become red-hot, and the connecting wires in vulcanised rubber.

The present rapid advance in electricity enables us to make direct use of the electric current without using a battery; surgery will soon make use of this modern acquisition also, and thus electrolysis will have a new field opened up for itself. We make use of electric light in many different ways in the performance of operations and for diagnostic purposes. Special illuminating apparatus have been devised for different parts of the body, such as the bladder, etc. For a description of the Roentgen rays, see § 124.

All wound surfaces made by the cautery bleed but little or not at all, and are thus in a manner protected from infection, as the micro-organisms present at the time are destroyed, and the resulting dry eschar is an unfavourable soil for the lodgment of new ones. Moreover, wounds made by burning granulate vigorously, heal quickly, and form a cicatrix which has a marked tendency to contract. Suppuration does not always occur, and often enough wounds of this kind heal beneath the eschar with no dressing and without noticeable suppuration.

Electro-puncture (Electrolysis).—The so-called galvano-puncture or electro-puncture (electrolysis) is but little used at present. It consists in inserting platinum or gold needles, which are connected with the poles of a strong battery, directly into the tissue but not too far apart. The changes thus induced in the tissues are limited to the immediate neighbourhood of the needles. In other cases only a single platinum

needle connected with the anode or cathode is inserted into the tissue in question—for instance, into a tumour—and a metal plate connected with the other pole is placed upon the skin. The negative pole (the cathode) appears to have a more powerful action than the positive (the anode). Recently electrolysis has come into more frequent use for operative purposes, especially in the case of tumours which are difficult of access, like naso-pharyngeal tumours and fibromata of the uterus, for strictures of the urethra, etc. In gynæcology the electrical treatment of women's diseases inaugurated by Apostoli has occasionally produced surprising results. I agree with Kuttner, that under certain conditions electrolysis offers us hopes of success, by being applicable to deeply seated regions, when other means fail entirely. Newman has obtained excellent results in stricture of the urethra. Generally speaking, the negative pole (cathode) is destructive in its action, while the positive pole (anode) acts as a hæmostatic.

Electro-puncture in Aneurism.—I have used electro-puncture in cases of aortic aneurism with very good results. It acts by exciting coagulation of blood in the aneurismal sac, which becomes diminished in size, and its walls are distinctly thickened. I use Stöhrer's zinc-carbon battery, and regulate the current by a dynamometer and a fluid rheostat. By means of the first the strength of the current can be determined each time it is used, and by means of the rheostat, made of a mixture of concentrated sulphuric acid and oxide of zinc, the process is made as painless as possible, since at the beginning one can allow the stream to increase in strength very gradually. At the close of the sitting the current is made to gradually decrease in strength by means of the rheostat. A sterilised fine steel needle, ten centimetres long, is plunged into the aneurism with every antiseptic precaution, the needle being connected with the anode, as the latter is preferable for causing coagulation of the blood, while the other pole (the cathode) is attached to a metal plate which is placed on the skin on the opposite side of the thorax. The length of the sitting should be five to ten minutes, and the strength of the current twenty to thirty milliampères.

The Destruction or Division of Tissue by Chemicals.—*Caustics.*—There are solid, soft, and fluid caustics which are used in the form of a paste, powder, or a fluid. At present caustics are used much less often than formerly for the destruction of soft parts. Of the solid caustics the most important are hydroxide of potassium or caustic potash, nitrate of silver, and sulphate of copper (bluestone).

Caustic Potash.—Caustic potash is applied in the form of a stick in a holder, thumb forceps, or wrapped in a piece of cotton for a handle. The most useful holder is an instrument made like a pair of pincers, having hollow jaws, with a contrivance for closing them made in the form of a movable blunt hook. As the caustic has a tendency to spread and "run" while being used, it is wise to carefully protect the surrounding parts. An old-fashioned way was to form an eschar on the skin by applying caustics between two pieces of sticking plaster, the one next the skin having a hole

cut in it to permit the caustic to act upon the skin. This dressing was applied to any particular portion of the skin with compresses and bandages for six to seven hours, until the eschar formation was completed.

Nitrate of Silver.—Silver nitrate comes in the form of a cylindrical pencil, which is generally provided with a handle, and is applied to hasten the skinning over of a granulating surface. The sticks of silver nitrate which, like our ordinary lead pencils, are enclosed in a wooden sheath, are most excellent. The so-called "modified stick" of silver nitrate is made of nitrate of silver and saltpetre (equal parts, or one part of the former to two of the latter). These sticks are less brittle and have a milder action. The action of bluestone (sulphate of copper) is still milder, and this material is used almost exclusively in diseases of the eye.

Other Caustics.—Among fluid caustics are the mineral acids, the most useful being concentrated sulphuric acid and fuming nitric acid. Besides these there should be mentioned hydrochloric, acetic, monobrom-acetic, and bichlor-acetic acids; also concentrated solutions of lactic acid, caustic potash, bichloride of mercury, chloride of zinc, chromic acid, antimony, etc. The fluid caustics are injected into the tissues by a hypodermic syringe, and this can occasionally be practised in inoperable cases, such as tumours. Of the milder caustics, the best known are the so-called "Vienna paste" and the pastes consisting of arsenic and of chloride of zinc.

Vienna Paste.—To make Vienna paste, five parts of caustic potash and six parts of quicklime are made into a thick paste, immediately before using, by the addition of the necessary amount of alcohol. The paste is then spread about five millimetres thick, by a wooden spatula, over the area selected for cauterisation, and allowed to remain from four to fifteen minutes, or until the desired effect is obtained. After six minutes at the latest there appears at the edge of the paste a gray line, which indicates that cauterisation or eschar formation is taking place in the area covered by the paste. After the removal of the paste the skin which it covered should be washed off with vinegar.

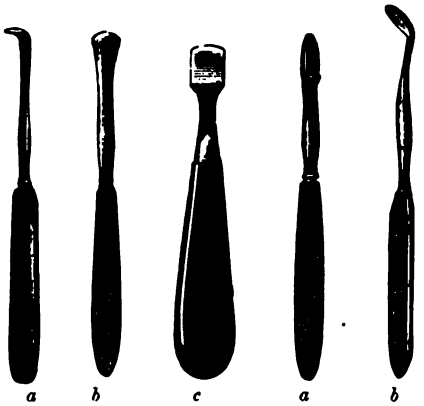
Arsenic Paste.—Make a dough of one part of arsenious acid and fifteen parts of starch and water. The eschar forms after a few days, during which there is severe pain. If too much paste is applied symptoms of poisoning are very apt to appear.

Chloride-of-Zinc Paste (Canquoin's Paste).—One part of chloride of zinc and two to four parts of flour, according to the amount of cauterisation desired, are mixed with just enough water to make a rather thick, stiff dough. The thicker the dough is spread out over the skin the more intense its action. Before applying the paste the epidermis should be removed, as it resists the cauterising power of the chloride of zinc. The action of this paste is very painful.

Rivallié's Caustic.—Rivallié has introduced a useful caustic. By dropping concentrated nitric acid upon charpie or cotton-wool in an earthen vessel there results a gelatinous mass, which can be picked up with forceps and applied to the skin, and after a quarter to half an hour a yellow circumscribed eschar forms. After about twenty-four hours the eschar can be for the most part separated, and the cauterisation may then be repeated. Not the smallest amount of bleeding results, even though the caustic be left in place for twenty-four hours, and the pain is very slight.

Caustic Points.—In conclusion, mention should be made of of cauterisation used by Maisonneuve (*cautérisation en fléches*). painful and slow procedure, which at present is scarcely eve means of a sharp-pointed bistoury the superficial portion of incised in lines radiating to its base, or else the base is punctured all around, and in each of these punctures there is introduced a lo solid stick of some caustic, or the incisions are filled with pieces strips of linen soaked in some fluid caustic.

§ 26. **The Division of Bone.**—We use the so-called ras periosteal elevator before dividing a bone, in order to raise serve the periosteum—as, for example, in the subperiosteal r the bone near a joint. The ends of raspatories—i. e., their l sharpened (Fig. 79), curved (Fig. 79, *a*) (Fig. 79, *b*, *c*). Elev to pry off the perios out cutting it, and ar blunt-edged, and eith or slightly curved (F or they are sometin like a goat's foot (Fig



a *b* *c* *a* *b*

Fig. 79.—Raspatories. *a* and *b* are Langenbeck's, *c* is Ollier's. Fig. 80.—Elevators.

To remove a part or to completely div use chiefly the chisel bone forceps and the

Chisels, which ar the best steel, have eith (Fig. 81, *b*, *d*) or flat blades (Fig. 81, *a*, *c*, *e*). Instruments wi lar cutting edge (Lauenstein) are also useful in some cases. much in strength, breadth, and length, and have their edg across or slanting. It is better to have the handle made no but of metal, in order that the sterilisation of the chisel may be more complete. The hammers used in chiselling are made of wood or metal. For dividing the large hollo use the broadest form of chisel, as is recommended by Kö for these large, broad chisels I prefer wooden handles, be easily replaced if they become damaged by boiling in cent. soda solution. They are not to be applied at rig but obliquely to the long axis of the bone. In cases w necessary to chisel at some depth below the surface, and possible to keep perfect control of the action of the chi recommends that the chiselling be performed with three h an assistant holds the chisel while the operator does the h

and with the index finger of his other hand controls the blade of the chisel.

The cutting bone forceps (Fig. 83) or bone shears (Fig. 84) is used to remove projecting angles or portions of bone, or to completely

Fig. 81.—Chisels.

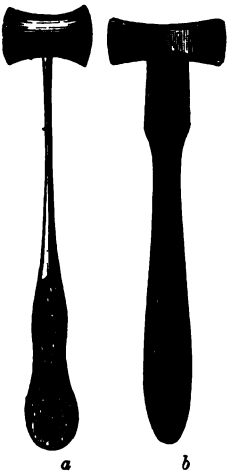


Fig. 82.—Hammers for the chisels.

divide a flat bone like a rib, the lower jaw, etc. The rongeur or gouge forceps of Luer (Fig. 83, *d*) can also be used for holding a bone. The

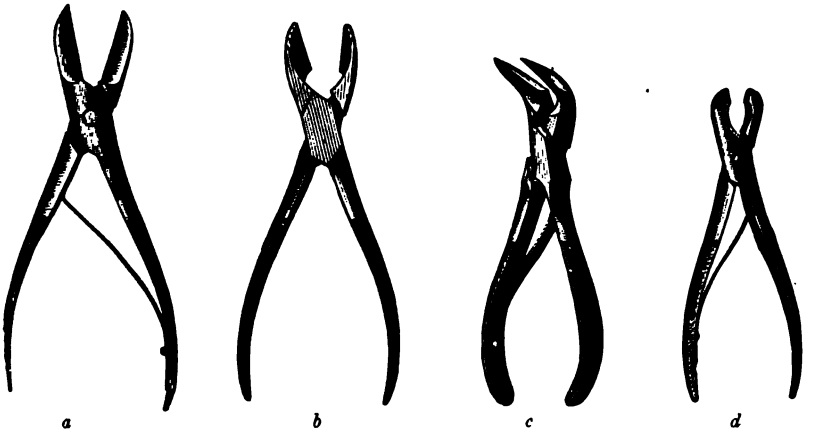


Fig. 83.—Bone forceps. *a* and *b* are Liston's, *c* is Roser's, *d* is Luer's.

best forceps for grasping a bone, etc., is that of Langenbeck (Fig. 85). The bones of children, particularly the soft, half-cartilaginous epiph-

yses and spongy bones, like the carpal and tarsal bones, can often be divided with a knife. The short, strong resection knife is the best suited for this purpose.

FIG. 84.—*a*, Bone-cutting forceps; *b*, bone-cutting forceps for use in resection of ribs; *c*, the two halves of *b*.

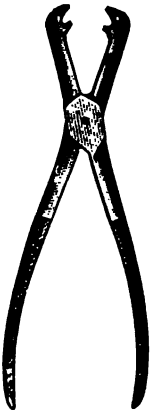


FIG. 85.—Forceps for holding a bone (Langenbeck).

For sawing bone we use bow saws (Fig. 86), narrow-bladed (Fig. 87), and chain saws (Fig. 88). The broad, flat saws have now passed

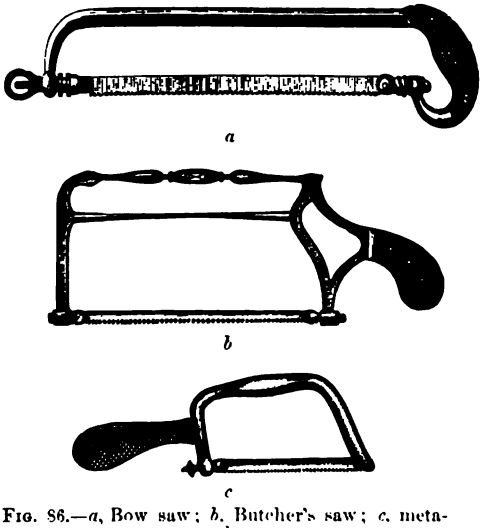


FIG. 86.—*a*, Bow saw; *b*, Butcher's saw; *c*, metacarpal saw.

FIG. 87.—Phalangeal or key-hole saws; *a*, *b*, Adams's.

entirely out of use. Butcher's saw (Fig. 86, *b*) is a very good one; its blade can be drawn tight or relaxed by means of the screw in the top-

most crossbar, the latter being connected by a hinge joint with the two bars running at right angles from its extremities. Thus these two bars, by means of the hinge joint, can exert traction in the line of the long axis of the saw blade, and the latter can make a curved cut in bone. For dividing small bones like the phalanges the so-called phalangeal (Fig. 86, *c*) or narrow-bladed saw is used (Fig. 87). The latter saw can be introduced through a punctured wound in the soft parts. For many operations Adams's narrow-bladed saw is one of the best (Fig. 87, *b*). Jeffray's (1784) chain saw (Fig. 88) consists of numerous links connected by hinges, and each extremity of the chain is provided with a hook for connecting it with the handles.

Fig. 88.—Chain saw.

Fig. 89.—Flexible director for the chain saw.

The chain saw is carried around behind the bone either by the hand, or a ligature threaded on a blunt curved needle, or a curved probe with an eye at the end, or by an instrument like the one illustrated in Fig. 89. The guide in Fig. 89 is provided with an eye for the thread, by means of which the chain saw is brought in position for use — for example, behind the neck of the femur. The earlier instruments of this class were made of steel or iron; but I have substituted for them a copper rod which can be bent and which has a steel handle, and thus I can give it any bend I desire. The chain saw should be handled gently, and with moderate traction exerted at the most obtuse angle possible. If too much force is used the chain may break, and

Fig. 90.—Dental engine with different kinds of drills and saws which are inserted at *a*.

if the tension upon the chain is uneven it may become jammed the bone. If this occurs the saw should be pushed back a little wi the thumb and index finger. Gigli's fine flexible wire saws are ve useful and cheap.

Rotation Saws.—Ollier, acting on the suggestion of the circular sa so widely used in the arts, has invented a "rotation saw" which worked by a crank, and by means of which pieces of bone of any desir shape and size can be cut out. The dental engine (Fig. 90), with i differently shaped burr drills, is used a good deal in surgical operation such as trephining, suturing bone, making holes in bone, etc. A dri with a handle attached is to be preferred to the machine shown i Fig. 90, as it can be controlled more exactly. In place of the dent engine, which is worked by the foot, I use at present an electr

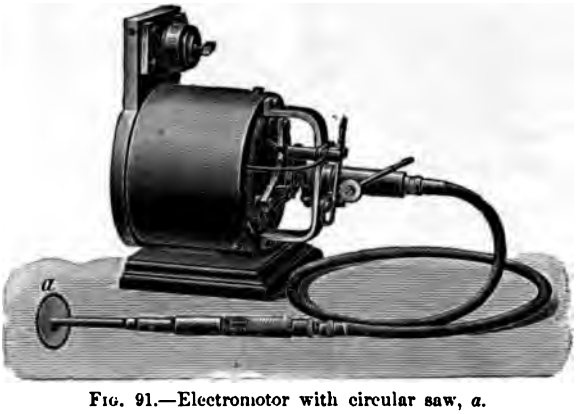


FIG. 91.—Electromotor with circular saw, *a*.

motor which is set in motion by an accumulator. My electromot has a rheostat and a movable stand. I use it for sawing, suturin and making holes in bone, and for centrifugal purposes. As tl motor only requires a current of 1.3 to 1.5 milliampères, the acc mulator ordinarily used for an illuminating apparatus can be employ for this motor. Mention should finally be made of the differe forms of trephines which are used for making circular openings the skull.

Among other instruments used in bone operations are the sha spoons (see page 77) for scraping bone which has become inflamed a broken down; also the different kinds of drills for making holes bone—for example, to insert a bone suture (see Fig. 110). The bo files for smoothing and rounding off the edges of a bone—for instanc after it has been sawed across—are no longer used, but their place h been taken by the simple chisel or Liston's bone forceps.

Osteoclasis.—Either the hands of the operator or special instruments (osteoclasts) are used to fracture a bone (osteoclasis) when, for example, a fracture has healed in a faulty position, or when there is a curvature of bone resulting from rhachitis. Collin, Robin, Mollière, Ferrari, Beely, and Gratteau have each devised osteoclasts.

In spite of the manifold improvements in the osteoclasts the instruments cannot even yet be relied upon to do all that their inventors claim. Above all, it is very difficult to fracture a bone at exactly the desired spot, especially if it is in the neighbourhood of a joint, without doing some injury to the soft parts.

CHAPTER VI.

THE METHODS OF ARRESTING HÆMORRHAGE.

The tying of vessels (ligation).—Artery clamps.—The preparation of aseptic ligature material (catgut, silk, etc.).—The substitutes for ligation.—Torsion.—Deep suture.—Temporary occlusion of the lumen of the vessel by artery clamps.—Ligature of a part of a vessel's wall and suture of veins.—Pressure.—Packing.—Cauterisation.—Other methods of controlling hæmorrhage.—Irrigation with hot and cold water.—The suture of the wound, with application of pressure by the dressings as a means of stopping hæmorrhage.—Old-fashioned and no-longer-used methods of stopping hæmorrhage (acupressure, acutorsion, etc.).—Ligature of vessels in their continuity. See also §§ 18 and 19 (Prevention of Hæmorrhage in Operations, Esmarch's Artificial Ischæmia).

§ 27. **The Arrest of Hæmorrhage during Operations.**—We distinguish between arterial, venous, and capillary or parenchymatous hæmorrhage. We shall here discuss, in the first place, the arrest of hæmorrhage during an operation.

The arrest of hæmorrhage from a wound made in the course of an operation must be most carefully attended to, in order that no secondary hæmorrhage may interfere with the healing of the wound or endanger the life of the patient. It is, in general, an indispensable requisite for obtaining perfect primary union that all hæmorrhage should be checked completely. In the presence of dangerous hæmorrhage the qualities of a surgeon are revealed; coolness, presence of mind, and complete familiarity with the technique of operating are indispensable. We have already learned, in the consideration of Esmarch's bloodless method, in what way serious hæmorrhages may be prevented in any operation.

The first step in accurately checking hæmorrhage consists in tying off (ligation of) the vessels, both veins and arteries, which have been wounded in the course of the operation. If, for example, in a high amputation of the thigh, or disarticulation of the femur, the femoral vein is not ligated, it is perfectly possible for dangerous recurrent or secondary hæmorrhages to take place; and as a matter of fact this has been observed.

Attempts to diminish or prevent hæmorrhage during an operation are as old as surgery itself. We recall with a shudder the times when amputation of a limb was performed with a red-hot knife, or when the amputation stump was plunged into melted pitch to check the bleeding. The skilful surgeons of the time of the Roman Empire understood the treatment of hæmorrhage better than the physicians of the middle ages, were familiar with the ligature, and even used artery clamps. All this was entirely forgotten during the middle ages, and Ambrose Paré reintroduced the ligation of vessels in the sixteenth century.

We tie off or ligate the vessels in the wound by seizing their open ends with so-called artery clamps or hæmostatic forceps, which are closed and locked by a suitable contrivance (Fig. 92). The Fricke-

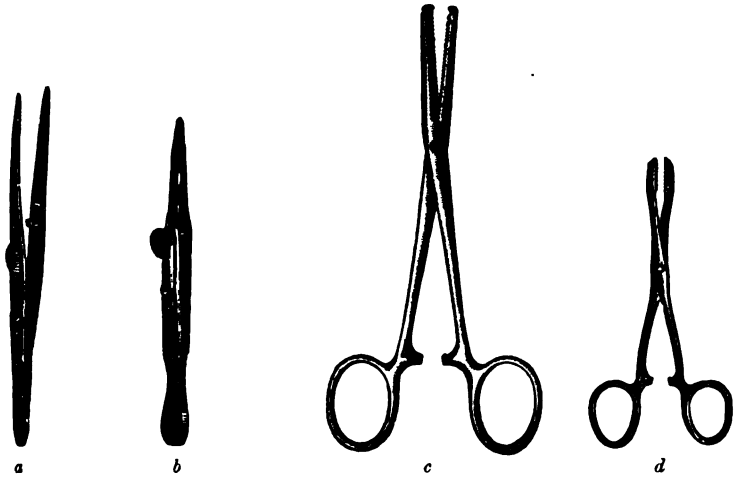


Fig. 92.—Hæmostatic forceps or clamps.

Amussat clamp (Fig. 92, *a*, *b*), which is fastened by means of a small sliding piece the end of which fits into a ring in the other jaw of the forceps, is no longer used. I make use entirely of the clamp shown in Fig. 92, *c*, which differs from the similar instrument of Péan and Kœberle in having teeth at the tip, and hence takes a firm grasp of the tissues.

By means of the hæmostatic forceps or clamps the isolated end of the vessel is seized, and, if necessary, the surrounding tissues are stripped back and the vessel is carefully encircled with catgut or silk, which is then tied beyond the clamp. In the case of large arteries the ligature should be tied in a surgeon's knot; but small vessels only require the ordinary square knot. The ends of the ligature are cut short after the clamp has been first removed to see whether the knot holds securely, and whether there is any danger of its slipping.

The surgeon's knot is made by twisting one end of the ligature arounc the other—not once, as in tying the ordinary knot, but twice. Th· application of ligatures *en masse*, as they are called, about the vesse and the surrounding tissue should be avoided as much as possible Instead of hæmostatic forceps or clamps, sharp-pointed hooks ar· sometimes used to draw out the end of the vessel. If for any reaso· it is impossible to tie a bleeding vessel, one of the other methods o stopping hæmorrhage described on page 97 may be employed.

Ligature Materials.—Ligatures are made of catgut, which is pre pared from the intestine of the cat or sheep, and of silk. Catgut i absorbed and disappear completely, while silk, o· the contrary, remains i· the tissues. In the liga tion of large arteries an· veins I prefer silk to cat gut, as the latter may be come absorbed before th vessel has become def nitely occluded, and i this way serious secon· ary hæmorrhage may r· sult. Furthermore, sil can be sterilised simpl and completely by boiling, while the sterilisation of catgut is still unce· tain in spite of the recent improvements in the methods. For th reason I prefer silk. The latter has another advantage in that fin· ligatures can be used than in the case of catgut. Silk and catgut a· kept in glass receptacles similar to those shown in Fig. 93.

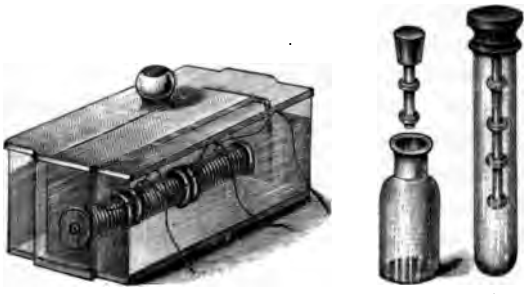


Fig. 93.—Vessels for storing sterilised catgut and silk: 1, Glass case with glass spools for hospital practice; 2 and 3, glass bottles with glass rollers and India-rubber stoppers for private practice (see also Fig. 18).

Preparation of Aseptic Catgut.—There are many methods for killing t germs in raw catgut, but none is so simple and sure as the preparation of si —viz., by simply boiling it in water. The surgeon who makes use of catg· must see that its sterilisation is carried out with the greatest care, and mu have it frequently tested bacteriologically. The aseptic methods of steri sation are to be preferred to the antiseptic, because the aseptic ligatures not irritate the tissues. Of the different methods of sterilisation about to described, I prefer Krönig's cumol method and my formalin method. Ev when catgut is germ free it may give rise to suppuration of a benign chara ter, due to chemical products of decomposition in the catgut. This probab results from preparing the catgut from intestine that is not perfectly fres It is hence very important to obtain a reliable raw catgut. The existence such numerous methods of sterilisation shows how hard it is to get a real sterile catgut. It is very important to make from time to time bacteriologic examinations of the fluid in which the catgut is kept, and of the catgut itse

Sterilisation by Dry Heat.—The raw catgut must first be soaked for twenty-four to forty-eight hours in absolute alcohol to remove all water. Then the catgut is put in glass tubes, or between layers of blotting paper, or in sealed envelopes, placed in the dry steriliser, and the latter heated very slowly (in three hours) to a temperature of 130° to 150° C. The catgut is then treated for three hours more to a temperature of 130°, and finally the steriliser is cooled off slowly. After this it is placed for six to eight days in oil of juniper which has also been sterilised by heat, and then it is stored for use in a one-per-cent. alcoholic solution of bichloride of mercury, or in a ten-per-cent. solution of carbolic acid in glycerine, or in a 1-to-500 aqueous solution of bichloride of mercury. Brunner places the catgut in xylol in a closed vessel, and subjects this to the action of steam at a temperature of 100° C. (212° F.) for three hours. The catgut is then washed in alcohol and stored in an alcoholic solution of bichloride of mercury.

Krönig's Cumol Method.—Krönig boils the catgut in cumol, a hydrocarbon compound of which the boiling point lies between 168° and 178°. He has used this method in the following way in his gynæcological clinic at Leipsic, and has found it very efficient: 1. The catgut is wound into rings, which are made to keep their form by tying three or four pieces of string loosely about each. 2. The catgut rings are heated slowly to a temperature of 70° C., and this temperature is maintained for two hours. 3. The rings are placed in cumol, and heated in this fluid upon a sand bath to a temperature of 155° to 165° for an hour. 4. They are then placed in petroleum benzine for three hours in order to remove the cumol from the catgut, and are kept in a sterilised glass vessel.

Chromicised catgut, which is more slowly absorbed, is prepared from commercial raw catgut by subjecting it to a dry heat of 130° C. (266° F.), and keeping it for forty-eight hours in a ten-per-cent. solution of carbolic acid in glycerine, and then for five hours in a one-half-per-cent. solution of chromic acid. It is stored in a five- to ten-per-cent. solution of carbolic acid in glycerine, or in a one-per-cent. alcoholic solution of bichloride of mercury, and immediately before use it is placed in a three-per-cent. aqueous solution of carbolic acid or bichloride of mercury. Macewen keeps the raw catgut for two months in a mixture of twenty parts of glycerine and one part of a twenty-per-cent. aqueous solution of chromic acid. He then washes it and stores it in a twenty-per-cent. solution of carbolic acid in glycerine.

The Schimmelbusch Method (Bergmann's Clinic).—The glass vessels that are to hold the catgut and the glass spools are sterilised by steam for three quarters of an hour. The raw catgut, which contains fat, is rolled on spools and soaked for twenty-four hours in ether, which is then poured off and replaced by an alcoholic solution of bichloride of mercury (one part bichloride, eighty parts absolute alcohol, and twenty parts distilled water), which is removed at the end of twenty-four hours. According to whether one desires stiff or pliable catgut, the latter is stored in absolute alcohol or in a twenty-per-cent. mixture of glycerine and alcohol, or in the alcoholic solution of bichloride just described.

Braatz's Method.—The raw catgut is soaked in ether or chloroform for one or two days to free it from fat; it is then placed for twenty-four hours in an aqueous solution of bichloride of mercury (1 to 1,000), or else

sterilised by the dry heat method (see page 95), and then stored in absolute alcohol.

Brunner's Method.—According to the investigation of Brunner, the catgut sterilised by treatment with bichloride of mercury or by dry heat is perfectly sterile, while the catgut treated with carbolic acid, chromic acid, and oil of juniper often contains fungi and bacteria. He recommends the following method: The raw catgut is first scrubbed with green soap, and then, either immediately or after soaking for half an hour in ether, it is transferred to an aqueous solution of bichloride (1 to 1,000), where it is left for twelve hours. It is then stored in bichloride of mercury, one part; absolute alcohol, nine hundred parts; glycerine, one hundred parts.

Repin's Method.—The fat is first removed in ether or carbon disulphide. It is then dried in an oven in which the temperature is gradually raised to 110° C. The next step is to place it immediately, before it takes up water, in a tightly closed vessel containing absolute alcohol, and heat it in an autotherm at a temperature of 120° C. for one hour.

Barthe's method is similar to the last. In order to obtain a less brittle catgut he subjects the same, after removal of the fat, to a hot current of air (80° to 95° C.) in a special vessel. He then places the catgut spools in small tubes closed with cotton, and subjects them to a vapour of alcohol, free from water, at a temperature of 120° C., and under a pressure of four atmospheres.

Method of Halban, Hlavaček, and Hofmeister.—One layer of raw catgut is wound on rods of glass or nickeled iron, and hardened in two- to four-per-cent. formalin for twelve to forty-eight hours, or in a five- to ten-per-cent. solution for twelve hours. The excess of formalin is then removed by washing it off in running water for twelve hours (Hofmeister). The catgut is next boiled in water for fifteen to twenty minutes, and finally hardened and kept in absolute alcohol, with the addition of five per cent. glycerine and four per cent. carbolic acid or one per cent. bichloride, depending upon whether metal or glass rods have been used.

Author's Formalin Method.—One layer of raw catgut is rolled on glass spools and placed for twelve to forty-eight hours in four-per-cent. formalin. The spools are then washed off with running water for twelve to twenty-four hours. The catgut is next boiled in water for fifteen to twenty minutes and then placed in absolute alcohol for six hours. It is kept in oil of juniper.

Saul's Method.—The raw catgut, suitably wound, is placed in a specially constructed boiling apparatus containing eight hundred and fifty parts absolute alcohol, fifty parts carbolic acid, and one hundred parts distilled water. The apparatus is heated to 75° C., and then the size of the flame reduced so that the temperature rises gradually to the boiling point (78 to 80° C.), which is allowed to act for fifteen minutes. The time consumed in sterilisation is forty-five minutes.

Harrington's Method.—Harrington sterilises catgut by means of formalin vapour. He employs the dry vapour, which does not weaken the catgut, whereas the moist vapour does.

Jacobi and Rosenbach recommend the impregnation of catgut with iodoform by placing it for six to twelve hours in a mixture containing iodoform, five parts; ether, twenty parts; absolute alcohol, fifty parts; and glycerine, twenty parts. It is kept either in the dry state or in a sterile fluid

which neither alters the catgut nor removes the iodoform—for example, glycerine, iodoform, oil, etc.

Preparation of Carbolised and Bichloride Silk.—The carbolised and bichloride silk is prepared by winding the silk on hollow glass spools and then boiling it for half an hour in a five-per-cent. aqueous solution of carbolic acid, or a 1-to-500 solution of bichloride of mercury. After this it is stored in a five-per-cent. aqueous solution of carbolic, or a 1-to-2,000 solution of bichloride of mercury, or in absolute alcohol. An aseptic silk ligature remains in a wound as a foreign body, but without causing any reaction.

Ligatures of Other Materials.—Besides catgut and silk, ligatures are made of chamois leather or parchment, from the aorta of the ox, from horse-hair, and from the tendons of mammals like the kangaroo, whale, reindeer, etc.

§ 28. **Substitutes for the Ligation of Vessels.**—*Torsion of the End of the Artery (Amussat), and Deep Suturing.*—Torsion of the cut end of a vessel is performed by seizing the end in a hæmostatic clamp and twisting it several times on its long axis. The lumen of the vessel is thus closed by rolling up and tearing the walls of the vessel, especially the middle and inner coats. Torsion produces more accurate closure of the lumen of the vessel if the latter is grasped by two clamps—one at the end of the vessel and held in its long axis, the other clamp behind the first and at right angles to the vessel. The clamp on the end is then twisted three or four times about the long axis of the vessel. Arteries as large as the axillary and femoral can be so firmly closed by torsion that no bleeding will occur. But if branches are given off close above the bleeding end of the artery, the latter will not be sufficiently movable to make torsion safe. Murdoch has used torsion successfully in a large number of amputations—viz., torsion of the femoral, 160 times; the popliteal, 24 times; the axillary, 24 times; the anterior and posterior tibial, each 405 times; the brachial, 115 times; the radial and ulnar, each 59 times. Stilling recommends drawing the end of the artery through a puncture made in the artery wall (Fig. 94). In this connection mention should again be made of Doyen's and Tuffier's method of hæmostasis called "angiotripsy," consisting in compressing the vessels by special forceps (angiotribe), without subsequent ligation (see also page 79).

Fig. 94.—"Durchschlingung" of an artery (Stilling).

Deep Suture around a Vessel ("Umstechung").—A suture passed through the tissues around a vessel is similar to a ligature *en masse*, because the surrounding tissues, as well as the vessel itself, are included in the ligature (Fig. 95). A sharply curved needle, carrying a ligature,

is passed through the tissues so that the points where it enters ar emerges lie close together. This method is applicable for those cas in which the bleeding end of the vessel lies, for instance, in stiff, u yielding tissues, or, for one reason or another, cannot be sufficientl isolated for the application of a separate ligature.

Hæmostasis by passing a Suture through the Skin and around a Vessel.—Middeldorpf's method of passing a suture through the skin and around a vessel is at best only a temporary expedient. For example, in bleeding from the temporal artery, a curved needle carrying a ligature can be passed through the skin, under the vessel and then knotted upon the skin. A similar plan is sometimes adopted to render operations on the tongue bloodless. At the end of the operation, when the wound in the tongue has been closed by sutures, this ligature *en masse* is removed.

Temporary Occlusion of the Vessels by Clamps.—For cases in which the application of a ligature is difficult or impossible, it may be expedient to occlude the lumen of a vessel by a hæmostatic clamp, which is left in place for some time. Kœberle and Péan have found the lumen of vessels perfectly closed after the expiration of twenty-four hours with this method of hæmostasis.

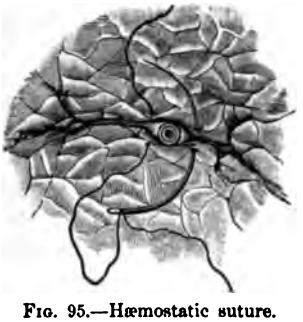


Fig. 95.—Hæmostatic suture.

Simple punctures or slits in the wall of a large vein have been closed by the application of a ligature to the side of the vessel. The injured portion of the vein is seized by a clamp, and, while slight traction is made upon it, a ligature is tied around the puncture beyond the jaws of the clamp, and thus the whole lumen of the vessel is not occluded. This lateral ligature is but little used, as it easily slips. If a large vein, like the common femoral, has been punctured, and there is fear of gangrene of the lower extremity if the whole vein is tied off, it is best to close the puncture temporarily with an artery clamp or by Schede's method of suturing with fine catgut. This suture of veins by means of the finest needles and catgut has been performed a great many times and with excellent results. Among the veins on which it has been done are the inferior vena cava, the axillary and the jugular.

Large arteries have also been successfully sutured. Manteuffel, for example, sutured the common femoral, Isran the common iliac (five interrupted silk sutures), and Heidenheim the axillary (continuous catgut sutures). In all three cases the sutures held perfectly, and no secondary hæmorrhage or circulatory disturbances followed.

Experimental Investigations on the Suture of Arteries and Veins.—The animal experiments made by Horoch, Jassinowsky, Murphy, and others in regard to the suture of arteries and veins have given favourable results. Suture of the wound in an artery resulted in a sure primary union, and there was no hæmorrhage after the operation. Some of the experimenters had in cases of secondary hæmorrhage, complete thrombosis, or aneurism form

tion, and the lumen became completely restored at the point of suture. Horoch, however, found that a gradual closure of the artery took place at the point of suture—not a sudden one, as in the application of a ligature. If a vein is sutured, the lumen persists to a greater or less degree, and consequently Horoch prefers suture to the application of a lateral ligature, as the experiments of Blasius show that lateral ligation of a vein regularly causes occlusion of the latter's lumen by a thrombus. Suturing of the vessel's wall is particularly applicable in longitudinal, oblique, and "flap" wounds, provided that not more than half the circumference of the large vessel is involved in the wound. The most rigorous asepsis is absolutely essential for success in suturing a portion of the wall of an artery, for which the finest silk is used in the form of a continuous suture with interrupted sutures through the adventitia and media. In the case of veins catgut can be used.

In case more than half of the circumference of the vessel has been divided, Murphy employs invagination of the two ends in place of sutures. He used this method successfully in the case of the femoral artery in the human subject. The method is as follows: After complete division of the partially divided vessel three sutures are inserted through the adventitia and media of the proximal end, and the ends of the sutures are carried from within outward through the distal end. The proximal end is then drawn into the distal end by means of the six threads. The latter are then tied and four or five interrupted sutures are passed through the projecting edge of the distal end and again through the adventitia and media of the proximal end. Finally, the sheath of the vessel is sutured.

§ 29. **Other Methods of Hæmostasis.**—*Pressure.*—Another most important method of hæmostasis is *pressure*, which we apply in many different ways, and which is evidently the simplest and most natural way of checking hæmorrhage. Whenever, during the course of an operation, blood gushes forth from a divided vessel, we immediately place our finger upon the bleeding point and so stop the hæmorrhage. It is singular that this simple method of hæmostasis is so little understood by the laity; when they meet with dangerous bleeding, perhaps from a punctured wound of one of the larger arteries, they are very apt to employ the strangest remedies, such as, for example, the application of cobwebs and similar things. Pressure is also practised as a temporary means of hæmostasis in the form of digital compression (mentioned in § 18, p. 54) of the afferent artery, and by means of rub-

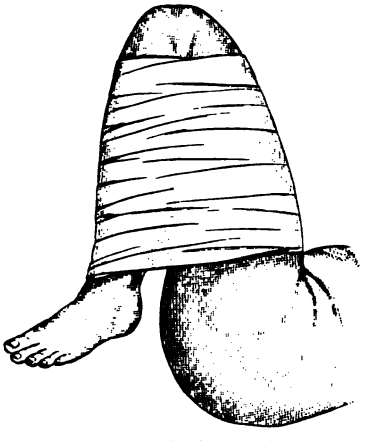


Fig. 96.—Forced flexion of the knee for temporary arrest of hæmorrhage in the popliteal space.

ber bandages, tourniquets, etc. In suitable cases pressure can be combined with forced flexion of the neighbouring joint—as, for example, in bleeding in the popliteal space the knee joint is immobilised in extreme flexion (Fig. 96), or hæmorrhage at the bend of the elbow can be held in check by immobilisation of the elbow joint in a position of extreme flexion.

Pressure is the ordinary method of hæmostasis used for stopping parenchymatous bleeding. The wound is compressed for a time with aseptic sponges, or is "packed" with some aseptic material such as iodoform gauze, or the dressing is bound on so as to exert pressure. In "packing" a wound or cavity such as the nasopharynx or rectum, we fill it as tightly as possible with some aseptic material such as iodoform gauze. Ligation of the bleeding vessels is, of course, much more reliable than this method.

Cautery.—Of the other methods for hæmostasis the hot iron is the most important, the best form of which is Paquelin's thermo-cautery (Fig. 73, p. 79) or Middeldorpf's galvano-cautery (p. 80). The firm eschar of the burn prevents the escape of blood. The cautery is usually only suitable for bleeding from small vessels which cannot be ligated. It should be used at not more than a red heat, so as not to burn the tissues too rapidly, but simply to char them slowly.

Styptics.—Among the fluid remedies for checking hæmorrhage mention should be made, in the first place, of liquor ferri chloridi, which makes a firm coagulum with blood. A pledget of cotton or gauze is soaked in it and applied to the bleeding spot as firmly as possible for one or two minutes. This procedure must usually be repeated one, two, or three times. Styptic cotton, as it is called, is simply cotton which has been soaked in liquor ferri chloridi and dried. The material made from the *Boletus igniarius* and the *Penghawar djambi* is very similar to styptic cotton, and consists of the light-brown hairs from the stem of the *Cibotium cuminghii*, an East Indian plant. If this is applied in sufficient amount to the wound surface and with enough pressure, it makes a very good styptic. Noltenius has recommended a penghawar cotton consisting of a mixture of *Penghawar djambi* with cotton and ten per cent. of iodoform. All styptics producing an eschar prevent primary union of the wound. Under fluid hæmostatics there are still to be mentioned vinegar, solutions of alum, turpentine, and aqua Binelli. Wright recommends a solution of fibrin ferment with one per cent. of chloride of lime as a useful hæmostatic, which does not produce an eschar. Cocaine has also a hæmostatic action, and for this purpose can be used in operations on the gums, in bleeding from the nose, etc. For the latter purpose cotton tampons can be used after soaking them in a twenty- to thirty-per-cent. solution of cocaine (also adding a little glycerine). Saint-Germain and Hénocque speak well of the hæmostatic action of antipyrine (either in a twenty-per-cent. solution or in the form of a powder). In cases of hæmorrhage from the genito-urinary tract Meisels has made successful use of cornutin (in doses of 0.01

gramme a day). In capillary hæmorrhage Reverdin recommends sodium sulphate in doses of a decigramme every hour as a very excellent hæmostatic.

Cold and Hot Irrigation.—We arrest capillary and parenchymatous hæmorrhage by pressure applied for a short time, especially by means of aseptic sponges or pads, by irrigation with ice water, or with water heated to about 45° C. (113° F.), and by suturing the wound and applying an antiseptic dressing tight enough to exert pressure. Ice water stops the bleeding by causing the capillaries and smallest vessels, together with the surrounding tissues, to contract, while water at a temperature of about 45° C. (113° F.) acts by directly promoting coagulation of the blood.

Suture of the Wound.—An important hæmostatic measure, as already mentioned, is the exact coaptation of the edges of the wound by means of sutures, especially in the case of parenchymatous bleeding, and in hæmorrhage from the smaller arteries, particularly those of the skin.

Pressure from Dressings.—The application of an antiseptic dressing which exerts pressure likewise checks or prevents subsequent parenchymatous oozing.

Elevation.—In the case of the extremities we possess a valuable hæmostatic measure in the form of elevation or suspension of the part, and in certain cases, particularly after the use of Esmarch's artificial ischæmia, which is apt at times to be followed by serious parenchymatous bleeding or oozing, this procedure is invaluable.

Ligature en Masse.—In a ligature *en masse* a considerable portion of tissue containing vessels is tied off with silk or catgut. The ligatures are carried through the tissues by means of a curved needle or a blunt aneurism needle (see Fig. 97, p. 103).

Acupressure and Acufilopressure.—Acupressure and acufilopressure (Simpson)—that is, compression of the vessels by long needles stuck through the soft parts (acupressure), or by needles thus inserted and having a thread wound around the projecting ends (acufilopressure)—are at present no longer used and will not be described.

§ 30. **Ligation of Arteries in Continuity.**—The ligation of arteries in their continuity is performed for injuries and for pathological conditions, notably aneurism. In case of severe hæmorrhage from an artery as the result of a punctured, gunshot, or transverse wound, it used to be the custom to ligate the artery at its most accessible portion, in the so-called place of election, proximal to the site of injury. This is not the best plan, on account of the frequency of secondary hæmorrhage from the unsecured wound in the artery after the collateral circulation becomes established. At present we search for the point where the artery has been wounded and tie the vessel on the proximal and distal

sides of the wound, and then extirpate the injured portion of the vessel lying between the two ligatures, and secure any branches which may be given off in the immediate neighbourhood.

As described under § 18, the ligation of arteries in their continuity is also performed as a prophylactic measure, to diminish or control hæmorrhage during an operation upon the region supplied by the artery in question. Under this heading comes, for example, ligation of the lingual arteries in extirpation of the tongue, of the femoral in disarticulation of the femur, of the axillary or subclavian in disarticulation of the humerus. Moreover, the afferent arteries of a part are sometimes ligated to check the growth of an inoperable tumour, and for elephantiasis—for instance, of an extremity, etc.

The operation, which is performed with every aseptic precaution, consists of two parts: (1) The exposure and isolation of the artery, and (2) the application of the ligature. In general it is best to use Esmarch's artificial ischæmia in ligating an artery of an extremity. For instruments we use a medium-sized scalpel, a straight and curved pair of scissors, two toothed thumb forceps, two dissecting forceps, several artery clamps, two retractors, a director, and an aneurism needle, with aseptic silk and catgut ligatures.

After carefully washing the field of operation in the usual way, shaving it, and disinfecting it with a three-per-cent. solution of carbolic acid, or with bichloride, 1 to 1,000, and placing the part in a convenient position, an incision six to eight centimetres long is made through the skin along the course of the artery. The fingers of the left hand hold the skin firmly stretched, or a fold of skin is lifted up and divided from without inwards, or transfixed and cut from within outwards. The skin is divided by one stroke of the knife. Then the operator and his assistant seize the cellular tissue at two opposite points with toothed forceps, and while it is gently lifted up it is divided between the two forceps with the knife to the full extent of the cutaneous incision. The remaining tissues are divided as in dissecting until the arterial sheath is reached. The sheath can also be reached very easily and quickly by pushing aside and tearing the tissues with a director, the handle of the knife, or the finger. It is advisable for the beginner to divide the connective tissue carefully upon the director. When the sheath of the artery has been laid bare it is well to make certain, by palpation with the finger tip, that it is the artery which has been exposed. Even though there be no pulsation, one can easily distinguish the firm, thick arterial wall, which can be made to roll under the finger, from the soft, thin wall of a vein. A nerve feels like a round solid cord. The operator then grasps the sheath of the artery with a

thed forceps or dissecting forceps, lifts it up from the artery, ns it with a knife or curved scissors or a director. Into the thus made in the sheath of the artery is inserted an aneurism or curved blunt hook (Fig. 97, *a*, *b*), in separate the artery itself on all sides e sheath. One should never free the rom its sheath to too great an extent, should carry out this step in the opera- gently as possible, to avoid unnecessary n of the artery and its sheath. When e circumference of the artery has been d from its sheath, an aneurism needle an aseptic catgut or silk ligature is nder the vessel, and after encircling r the ligature is tied fast around the Fig. 98). Two surgeon's knots supple- by a simple knot are usually considered y for the larger arteries. A surgeon's nade by twisting the ends of the liga- ce about each other, and not once, as ng a simple knot. Large arteries are secured by a double ligature, and the then divided between the central and al ligatures. If an artery is to be tied double—i. e., on the nd peripheral sides of the point of injury, perhaps a punctured -the aneurism needle is threaded with a double ligature, and r, after being placed around the artery, is cut at the loop, thus ne ligature for the central and the other for the peripheral of the artery. In passing the aneurism needle around the are must be taken to avoid injury to the neighbouring vein, and before drawing the ligature tight it must be ascertained that the artery alone is tied, and that a nerve is not included in the ligature. After tying the ligature its ends are cut short. If the operation has been performed with the aid of Esmarch's artificial ischæmia, the rubber bandage is now care- sened and then slowly removed. When the double ligature n tied and the intervening wounded portion of the artery has tirpated, the operator should always look out for branches

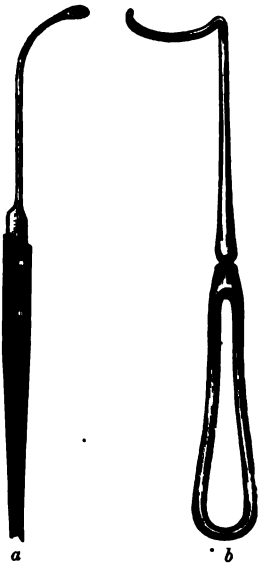
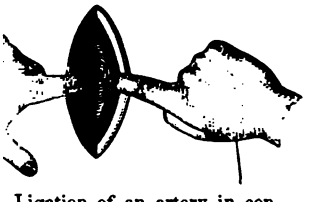


Fig. 97.—Aneurism needles.


-Ligation of an artery in continuity.

arising from this intervening portion, which should be secured wi- the same care as the main vessel, because there is a possibility of se- ondary hæmorrhage from these branches after the establishment of t collateral circulation. The wound is then either packed with gauze closed, with or without drainage. An antiseptic dressing exerting gentle pressure must then be applied, together with a splint in the ca of the extremities, so that the part which has been operated upon immobilised as completely as possible. Immediately after the arte has been ligated a collateral circulation takes place through t branches given off above and below the ligature (see § 61).

The ligation of particular arteries is taken up in the text-book c Regional Surgery.

The ligation of veins in their continuity is carried out in exact the same manner as described for arteries.

CHAPTER VII.

DRAINAGE OF WOUNDS.

Importance of drainage.—Different methods of draining a wound: leaving the wound open; aseptic packing; drainage by rubber tubes.—Absorbable drains.—Drainage tubes of glass, metal, etc.—Capillary drainage with strands of catgut, horse-hair, and glass wool.—Formation of openings in the skin.—Secondary suture.—Healing under a blood-clot without drainage (Schede).

§ 31. **The Method of allowing the Secretions of a Wound to Escape.**—*Drainage.*—In every fresh wound there is regularly an escape of a bloody, serous fluid, rich in albumin, from the divided tissues, the open capillaries, and lymph spaces, and it corresponds in amount with the size of the wound and the number of cavities and pockets. The formation of these cavities in the wound should be prevented, as far as possible, by sutures and by the application of a dressing exerting proper pressure. In small wounds the pressure exerted by the dressings is sufficient to obtain rapid healing, and it is not necessary to use means for carrying off the secretion except when suppuration is already present. But in case of suppuration, and in large fresh wounds, we must provide suitable channels for the escape of the secretion in the shape of drainage in some form. Unless we do this the secretion is retained in the wound and prevents primary union. Moreover, opportunity is given for the secretion to decompose and for pus to form, and, as a result of the retention of the pus or decomposed secretion of the wound, spreading suppurative inflammation or general infection of the whole system takes place from absorption of the infectious material (pyæmia, septicæmia). Consequently it is a matter of great importance to provide careful drainage in large clean wounds, and particularly in those which are already infected. At the present time attempts have been made to do away with drainage in wounds made in aseptic operations, but most surgeons still rely upon it. As a matter of fact, it is indispensable for the first twenty-four to forty-eight hours in large aseptic wounds, even after they have been closed by sutures—for example, after amputation of the breast, accompanied by cleaning out the axilla. The secretion from the wound and the effused blood can thus escape,

and so do not prevent the rapid agglutination of the opposed wound surfaces. There are various methods for enabling the secretion from the wound to escape.

The simplest of these is to leave the wound open without suturing it, or only partially suturing it, leaving the angles of the wound unclosed. Open, unsutured wounds are generally filled with some absorbent material, usually sterile, or iodoform gauze. This aseptic packing of a wound is an excellent method of drainage, as it absorbs the secretion from the wound and causes it to remain aseptic. When necessary, the packing can be fastened in place by sutures through the skin. Wounds which have been left open can then after a few days, when the packing is removed, be closed by secondary suture, as it is called, which hastens the healing process.

If we wish to immediately close large and deep wounds, which have not been infected, so as to obtain rapid healing with primary union—i. e., direct agglutination of the tissues without the formation of pus, as in amputations, resection of joints, extirpation of tumours, etc.—we take proper steps for conducting off the secretions of the wound by drains inserted into the deepest portions of the wound.

Drainage Tubes.—The ordinary drains are made of tubes of vulcanised rubber or glass provided with numerous lateral openings (Figs. 99 and 100). These drainage tubes should have as large a calibre as possible, and, while not being too long, they must always be so inserted as to render easy the escape of the secretions from any part of the wound, and therefore should reach into its deepest portions. Whenever possible, I place the drain to one side of the suture line and not directly beneath it, so as not to separate the suture line from the underlying parts and thus render it impossible for primary union to take place. Drains are passed through a wound with the aid of dressing forceps (Fig. 101) after the skin has been first incised with a knife and the remaining soft parts have been pierced by the forceps. The drainage tube is secured in its position by a stitch taking in a part of the end of the tube, or by a disinfected safety pin, and thus prevented from slipping into the wound. T-shaped tubes are

Fig. 99. Rubber drain.

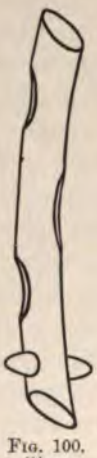


Fig. 100. Glass drain.

Fig. 101.—Drain forceps.

sometimes useful in preventing the drain from falling out of or slipping into the wound. A T-shaped drainage tube is easily made by splitting one end of a tube (Fig. 102, *A*) longitudinally and then drawing each end through a lateral opening in another tube (Fig. 102, *B*). The drain is removed from fresh wounds at the same time that the stitches are,

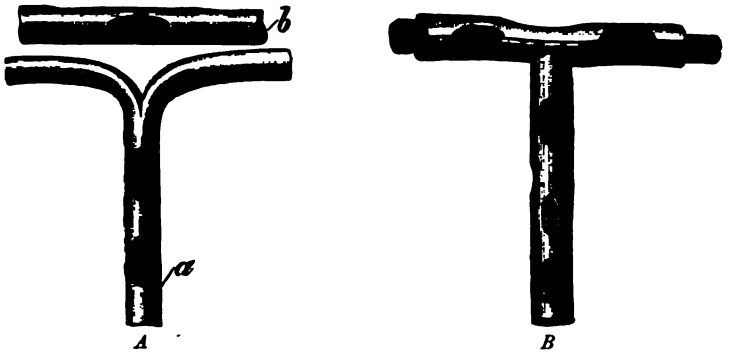


FIG. 102.—Construction of a T-shaped drainage tube.

or by the second, third, fourth, or seventh day, according to the nature of the case and the size of the wound. If it is a suppurating wound the drain is taken out when the suppuration ceases, and under such conditions it is best not to remove the drainage altogether at one time, but first to shorten the tubes and then gradually take them out.

I have recommended short drainage tubes of large calibre because they do not so easily become plugged up, and consequently there is no necessity for syringing them out with antiseptic solutions. This syringing out of drainage tubes should be avoided, especially in all fresh wounds produced in an operation. It can only do harm by irritating the wound and forcing apart again the already adherent wound surfaces. It is better to replace stopped-up drainage tubes, if necessary, by new ones. Even washing out a suppurating wound with antiseptic solutions by means of an irrigator (Fig. 103) is often entirely unnecessary, and may, indeed, do harm.

Hardening of Rubber Drainage Tubes.—In order to prevent rubber drainage tubes from becoming soft it is a good plan to first place them for five minutes (the thick variety longer) in strong sulphuric acid, then wash them in five-per-cent. alcohol and keep them in five-per-cent. carbolic or 1 to 1,000 bichloride. The orange-red drainage tubes are best suited to this process, the gray and black ones less so. The tubes that have once been hardened retain the stiffness of their walls even in the antiseptic solutions in which they are kept stored.

Absorbable Drainage Tubes.—Besides rubber drainage tubes, other forms have been used, such as absorbable tubes made of decalcified bone. The absorbable drainage tubes of decalcified bone have not come into very general use, because they are liable to be absorbed too quickly before they have accomplished their purpose.

Preparation of Absorbable Bone Drains.—Absorbable bone drainage tubes are made as follows: The long, hollow bones of fowls and other birds are freed from soft parts by boiling, and then placed for about ten or twelve hours in a mixture of one part of hydrochloric acid and two parts of water; the ends of the bones are cut off with scissors and their interior cleaned out with a stout wire, after which they are boiled in a five-per-cent. carbolic solution, to which Deakin adds some borax, and they are finally stored for use in the same solution.

Strands of Catgut as a Drain.—The smallest drain which we use consists of strands of aseptic catgut or horse-hair, which are laid side by side in the form of a bundle of threads. Kummel has recommended capillary glass drainage in the form of strands of spun glass.

Attempts have been made to substitute drainage by means of holes made in the skin for the ordinary drainage with rubber tubes in case of wounds directly under the skin, and the canalisation of skin and muscular tissue in case of deeper wounds (Esmarch and Neuber). To make a canal of skin and muscular tissue for purposes of drainage, the cut edge of the skin on each side is attached by a catgut suture to the wound in the muscular tissue beneath it.

Of all these different kinds of drainage, in my judgment the ordinary drainage supplied by rubber or glass tubes, or by packing the wound with sterilised gauze, is by far the best, and all other methods (strands of catgut, bundles of horse-hair, cutaneous punctures, canalisation, and absorbable drains) are only suitable for small wounds, and are insufficient for large, deep wounds in which there are pockets. If the drainage by rubber tubes is properly managed and the drains removed at the right time, it is easy to prevent the evil consequences which the tubes sometimes cause, such as necrosis of the skin, persistent fistulæ, etc. With a view to diminishing the amount of secretion in the wound it is very important that the same should be irritated as little as possible by antiseptics. Consequently we should operate by the aseptic method and keep the wound dry.

Kocher's Substitute for Drainage.—Kocher has tried to dispense with the drainage of the wound by covering it with a thin layer of subnitrate of bismuth. The latter is sprinkled over the wound in the form of a one-per-cent. mixture of bismuth in water, which is dropped out of a flask; or, if there is bleeding, compresses impregnated with bismuth are applied to the wound. The wound surface is so much dried up by the bismuth that the

secretion is almost *nil.* After twelve, twenty-four, or forty-eight hours the wound is closed by secondary suture.

Schede's Method of healing under a Blood-clot.—Schede has recently recommended "healing under a moist blood-clot"—e. g., he permits a cavity which has been hollowed out of a bone to fill with blood, closing the wound tight by suturing the skin and not inserting any drain. If the coagulum thus formed in the course of an aseptic operation remains aseptic, it will be gradually absorbed and its place taken by newly formed connective tissue or bone, and healing will occur without reaction. I think this method deserves a fair trial; it has proved of service to me after operations for caries and necrosis.

CHAPTER VIII.

SUTURE OF THE WOUND.

Disinfection of the wound and surrounding parts before inserting the sutures of the soft parts.—Needles, needle holders, and suture materials.—Differ ods of suturing the wound (interrupted, continuous, silver-wire sut suture, twisted suture).—Removal of the sutures.—Secondary suture.— suture.—Subcutaneous suture of nerves, tendons, muscles, etc.—Union surfaces in bones (bone suture).—Suture of the periosteum.—Nailing methods of uniting the surfaces of a divided bone.

§ 32. **Disinfection of the Wound before inserting the Sutures.** arresting the hæmorrhage very carefully and putting in the drainage, the wound and the surrounding parts are washed three-per-cent. solution of carbolic acid or 1 to 1,000–5,000 of bichloride of mercury. The irrigator (Fig. 103) is best su this purpose; it is made of metal—or, better, of glass—with a tube provided with a able tip made of glass ber, through which tl tion flows. A warnin be given against too cleansing of the woun antiseptics, because to irritation is produced, ensuing secretion fr wound will be increa irrigate wounds made an operation only in th in which there is the po of infection having occurred during the operation. Even wound is already infected and pus is present the strong antisep tions should be avoided. It is sufficient to cleanse the woun weak solutions or sterile salt solution, particularly as it is impo really disinfect by antiseptics a wound that has become infecte pathogenic micro-organisms present in the tissues are not killed

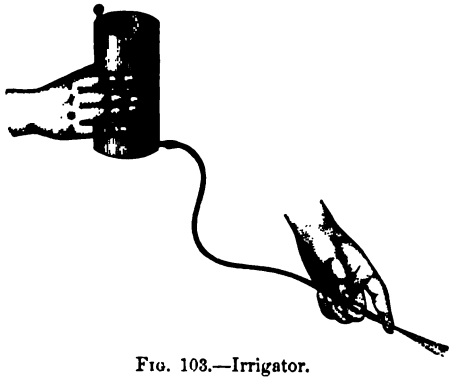


Fig. 103.—Irrigator.

If there are no irrigators at hand, clean aseptic sponges or gauze pads may be soaked full of the antiseptic solution or sterile water and squeezed out over the wound and adjoining parts. I keep the wound as dry as possible, but if it is necessary to wash out the wound I use sterile water or salt solution. If this is done the secretion in the wound is much less than when the irritating antiseptic solutions are used. The main point is always to operate with perfectly aseptic hands and instruments. When the hæmorrhage has been arrested and the wound treated on these general principles, we proceed to insert the sutures.

§ 33. **The Uniting of the Soft Parts—Suture of the Wound.**—In all cases in which we wish to obtain as speedy union of the wound as possible (*per primam intentionem*) we close the wound by suturing together its edges. Suturing should always be carried out with the same regard to asepsis as was had in the operation itself, and hence the needles and the sutures must be previously made aseptic.

For introducing sutures we use straight and variously curved needles with lance-shaped points. The recently introduced platinum-iris

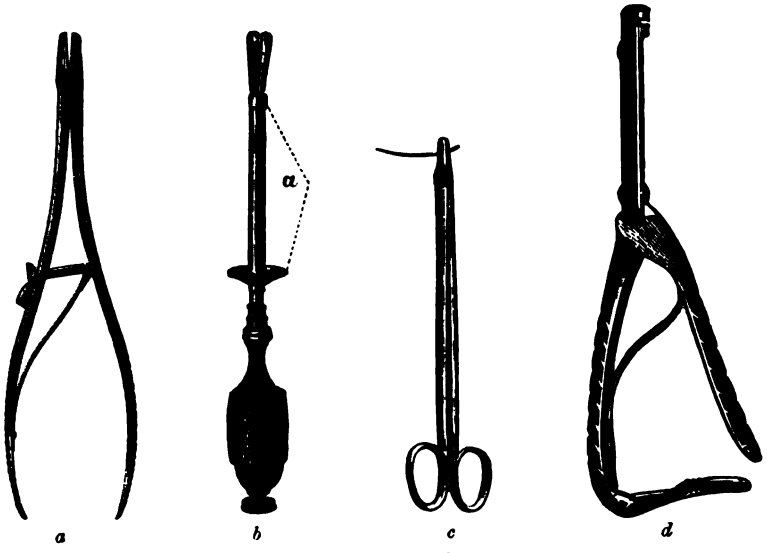


Fig. 104.—Needle holders.

needles possess the advantage of not oxidising, and they can be heated red-hot without losing their original temper. Besides the ordinary needles without handles, there are many provided with handles (I only use these in performing uranoplasty and staphylorrhaphy). When the needle cannot be introduced by hand, as in the mouth or pharynx, the

vagina, etc., we use a needle holder. Of the numerous different kinds of needle holders, those worthy of mention are the holders of Dieffenbach, Reiner (Fig. 104, *a*), Roux (Fig. 104, *b*), Sims (Fig. 104, *c*), Hagedorn (Fig. 104, *d*), and others.

Suture Material.—Sutures are made of sterilised silk, linen thread, catgut, horse-hair, sea-grass, silkworm gut (from the chrysalis of the silkworm), crin de Florence (from the intestine of the silkworm), silver wire, aluminium-bronze wire, etc. Catgut has the great advantage over silk that it is absorbable, and is therefore preferable for subcutaneous or buried sutures—that is, suture of nerves, tendons, muscles, etc. Moreover, buried catgut sutures are the best for uniting a ruptured perinæum; for the radical cure of hernia; for operations on the uterus, bladder, or intestine; and for operations on fistulæ. If catgut is used for suturing the skin, the sutures will not need to be removed with scissors, but after about four to seven days the external portion lying over the line of the wound can be simply picked off with forceps, as the part which lies buried in the tissues is absorbed, or is only very weakly attached to the rest of the suture. On account of this rapid absorption of catgut, it follows that under certain conditions catgut sutures will not hold the borders of the wound long enough in apposition. I generally use fine silk in suturing the skin. The preparation of a satisfactory catgut has been described on pages 94–97. The size of the catgut or silk suture required will, of course, depend upon the kind of tissues to be united and the amount of tension. When there is great tension strong sutures are naturally required, because fine sutures would easily cut through.

Silver wire should be made smooth before use by passing it through a flame till it becomes red-hot. Silkworm gut is excellent for tying off the pedicle in ovariotomy, for perineal operations, etc. In place of silver wire I have been using of late Socin's aluminium-bronze wire, which is cheaper, more pliable, and more resistant than silver.

Sutures made from the Tendons of Reindeer, Horses, and Deer.—Ratiloff uses the tendons of reindeer for suturing wounds. This material is used by the Siberian colonists for sewing. Putilow uses the tendons of horses and deer. The strips of tendon are soaked for twenty-four hours in ether, and for the same length of time in a five-per-cent. alcoholic solution of carbolic acid. The strips of tendon thus prepared are said to be stronger than catgut, as soft as silk, and completely absorbed in the wound.

The Interrupted Suture.—The most common form of suture is the so-called interrupted suture (Fig. 105). This is introduced with straight or curved needles, the aseptic catgut or silk being simply knotted in

of the needle, or, better, threaded so as to leave two long ends. t, especially if the suture is of large size, interferes with draw-ye portion of the needle through the skin. The border of id is seized with a toothed forceps, and the s pushed through first one edge of the and then the other. Both edges of the an be pierced at the same time, provided held together by an assistant. The knots e placed to one side of the line of suture. If much tension on the edges of the wound the surgeon's knot is occasionally used—that ids of the suture are twisted not once, but out each other. It is best to begin the ot at the ends of the wound, but in the especially if it is a long one; and at the nserting the first suture care should be taken the borders of the wound in good apposition, as otherwise me folds at the extremities of the line of suture may result.

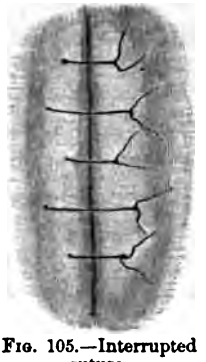


FIG. 105.—Interrupted suture.

different kinds of sutures are classed under the head of ed sutures: the tension suture and the coaptation suture. is inserted and brought out anywhere from one to six centi-rom the edges of the wound, while the second or coapta-ire is shorter, and the points where it enters and emerges about half a centimetre distant from the edges of the wound i).

e sutures by which correct apposition of the borders of a long re obtained are called apposition sutures. In every suture line est care is necessary to prevent the edges of the wound from g inverted, and the two borders must lie in good apposition h other. The sutures must not be drawn too tight. It must y be borne in mind that the successful healing of a sutured lepends upon the proper insertion of the sutures, and that applied unskilfully and without antiseptic precautions may to serious dangers. An erysipelas which may cause the death atient may start from a small spot of necrosis in the skin, aris-aps, from a portion of the border of the wound which has ed in, if the borders of the wound are not properly placed in n; or it may start from a small stitch abscess produced by rfectly disinfected needle or suture. Disastrous results may rom very small causes. Furthermore, no appreciable cavity e allowed to remain; and hence the deeper-lying parts are s united by special catgut sutures or are included in the cuta-

neous sutures. "Good suturing, good healing," was a favourite saying of Nussbaum.

Continuous Suture.—Instead of the ordinary interrupted suture I frequently use the continuous suture, and usually in combination with tension sutures (Fig. 106). I use, whenever it is possible, needles with lance-shaped points, of the same size as the ordinary tailors' needles. The fine suture, which should not be too long, is simply knotted in the eye of the needle. The number of tension sutures required depends, of course, upon the length of the wound. The tension sutures are inserted in the usual way, and then the continuous suture is begun at one end of the wound by making one ordinary interrupted suture; the thread, however, is not cut, but the suture is continued by transfixing at equal distances the opposed borders of the wound, which are held together by the fingers. When the other end of the wound is reached (Fig. 106, *a*) the suture is cut with scissors, and the three threads are knotted together like the ordinary interrupted suture, two threads being on one side of the wound and one upon the other. The suture can also be finished off by forming a loop through which the extremity of the suture is drawn. The continuous suture has the advantage over every other kind of being capable of very rapid execution, and of rendering excellent coaptation of the borders of the wound. If the wound is very long and there is fear that a single continuous suture will not be strong enough, the suture can be interrupted at any desired part of the wound, and from this point a fresh continuous suture can be begun; or it can be given greater security by tying it at any point and then continuing. But when the precaution of inserting tension sutures is taken there need be no fear that the continuous suture will prove at all untrustworthy if it is carefully inserted. Catgut is ordinarily the best material for the continuous suture, and I use aseptic silk for the tension sutures. The continuous suture is particularly adapted for operations on the peritonæum and the gastro-intestinal tract, and for the buried catgut suture in operations on the vagina for prolapse and for rupture of the perinæum.

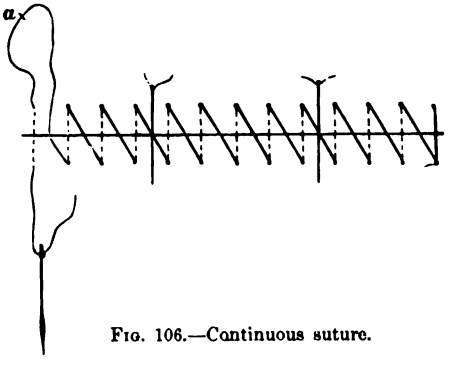


Fig. 106.—Continuous suture.

Subcutaneous Suture.—In order to prevent stitch-hole suppuration some surgeons use the subcutaneous suture, which consists in passing the needle

through the cutis parallel to the surface, as the purse-string suture. In this way the outer layers of the skin and the ducts of the skin glands which contain bacteria are not penetrated by the needle. The ends of the suture are tied at each angle of the wound over a small gauze roll.

Silver-wire Sutures.—If silver wire is used for suturing, it is fastened to a straight or curved needle by simply bending over one end of the wire after it is threaded through the eye. The silver-wire suture is fastened in place by exerting suitable traction on the wire and then simply twisting together its crossed ends, or an instrument particularly designed for the purpose may be used (Fig. 107). The cross-piece of the "wire twister" contains two round openings into which the ends of the wire are passed after they have been crossed over the wound, and then by rotating the instrument the wires are twisted around each other.

Fig. 107. Wire suture tightener.

Fig. 108.—Lead plates.

The Silver-wire Suture with the Lead Plate.—A form of tension suture which has at present somewhat gone out of use is the silver-wire lead-plate suture used for closing the wound after abdominal section or amputation of the breast. Small lead or glass plates are required which are perforated in the centre. The silver wire is either twisted around the plate (as in Fig. 108, *a*), or fastened to pins on its surface (Fig. 108, *b*), or else the silver wire is inserted in a small lead ring which is pinched together with forceps. Glass beads can also be used. The end of the wire is passed twice through the bead and drawn tight, then through the lead plate, and after attaching it to a needle the suture is inserted. Upon the other side of the wound the wire is first passed through the lead plate, then through one or more glass beads, and after obtaining the proper tension the wire is twisted around a sterilised match and the ends are cut short with scissors. It is a very good plan to use, instead of silver wire, a double silk suture and tie the two ends on each side over a glass bead, only one thread passing through the bead. Pledgets of iodoform gauze can also be used for securing the ends of the silver-wire lead-plate suture. At present I have given up this kind of suture, and prefer a tension suture of stout sterilised silk inserted some distance from the edge of the wound. The latter, furthermore, is more quickly inserted.

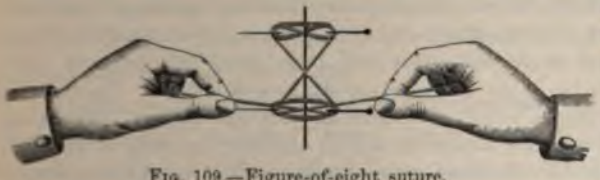


Fig. 109.—Figure-of-eight suture.

Other Methods of Suturing.—The old-fashioned continuous furrier's stitch, the fin stitch, and the looped suture are useless and out of date, and will not be described. The continuous suture which I have described differs materially from the continuous furrier's stitch. The so-called "figure-of-eight" or twisted suture (Fig. 109) I also consider unnecessary, and no longer use it. The interrupted suture answers the same purpose, is more simply inserted, and is better for the tissues. It is applied in the following way: The edges of the wound are transfixed by long Carlsbad needles some distance apart. About the ends of the needles is twisted an aseptic silk suture in the form of a circle or figure of 8, and the extremities of the thread are knotted together. The sharp ends of the needle are clipped off with a Luer's rongeur forceps.

The Removal of Sutures.—The stitches are taken out, in the majority of cases, at any time from the third to the seventh day, according to the kind of wound. We frequently—for instance, after plastic operations on the face—take out a stitch here and there at the end of twenty-four hours; but in other cases, on the contrary, as when the peritoneal cavity has been opened, we allow the stitches to remain till the eighth to the fourteenth day. In long wounds, and in those in which there is danger of the agglutinated borders of the wound separating after removal of the sutures, the latter should not all be taken out at the same time. The tension sutures, particularly at the extremities of the wound, when combined with the continuous suture, should be taken out first. If the tension sutures become buried in the skin—i. e., "cut out"—they should be removed immediately. Sutures are removed by seizing one end of the knot with dissecting forceps and, while slight traction is exerted, cutting off the suture close to the wound and carefully drawing it out. Care must be taken that the whole suture is removed. If catgut has been used it is unnecessary to cut the stitches with scissors, as the portion buried in the tissues is absorbed, and only leaves the exposed loop of catgut to be picked off the skin with thumb forceps.

Secondary Suture.—If the borders of the wound gape after removal of the stitches, the wound can be reunited by a fresh suture (secondary suture). This secondary suture is very much used—for example, in wounds which have been first packed, or in wounds which have been left entirely open during the first few days, or in deep, granulating wounds, etc. To avoid a repetition of the anæsthesia when secondary sutures are applied, Nussbaum has advised that the secondary suture be put in place at the time of the first operation. For example, a mattress or continuous suture should be inserted in advance in each margin of the wound, and then, later, the loops of these sutures can be used to close the wound by passing a silk thread through them.

Stitch-hole Suppuration.—Stitch-hole abscesses are caused in part by the bacteria in the skin and cutaneous glands whose presence is due to incomplete sterilisation of the field of operation, and in part by the use of non-

sterile needles and sutures. In putting in buried sutures, the latter should not be too numerous nor drawn too tight, as necrosis followed by suppuration may easily result. Catgut sutures made from poorly prepared material containing toxines may cause non-bacterial suppuration. (Poppert.)

Bloodless Suture.—The bloodless or dry method of suture has gone entirely out of use. The Arabs used, for closing a wound, an insect (*Scarites pyræmon*) whose maxilla terminated in a small hook. The borders of the wound were approximated by these hooks, the body of the insect being removed and leaving only the head with its hooks. Vidal de Cassis attempted to imitate this method of approximation with his *serre-fine*.

The suture of tendons, nerves, etc., is described in the third section (§ 88, Injuries, Wounds), and suture of the intestine, bladder, etc., is treated in the text-book on Regional Surgery.

§ 34. **The Method of uniting Wound Surfaces of Bone.**—The surfaces of a wound in a bone can be held in apposition by periosteal sutures only when small bones are concerned. A suture passed through the bone itself is, of course, the best. The necessary holes are made through the bone by means of the dental boring machine (Fig. 90, p. 89), the electromotor (Fig. 91, p. 90), or a bone drill (Fig. 110). The latter is worked by pushing the metal spool on the instrument up and down and thus causing the needle to rotate. Heavy catgut, silver wire, or aluminium-bronze wire are used as suture materials. J. Henequin (Rev. de Chir., August, 1892) and V. Wille (Centrbl. für Chir., 1892, p. 46) have recommended a very good method of bone suture. Wille's plan consists in boring a hole through both walls of a hollow bone and dragging the silver wire through it by means of a peculiar "suture hook." Dollinger recommends a method of bone suture without making holes in the bone. He winds a piece of wire about each end of the broken bone and then fastens the bones together by two longitudinal pieces of silver wire which he attaches to the circular wires.

Fig. 110.—Drill for bone sutures.

Another excellent method of uniting the surfaces of a wound in bone is aseptic nailing. Long, four-cornered nails are used, which are first very carefully polished and then sterilised by boiling in a five-per-cent. carbolic-acid solution. After some three or four weeks the loosened nails can be easily drawn out with forceps or the fingers and without causing the patient pain. Of course, care must be taken that the nails project at least two centimetres beyond the level of the skin. Long ivory pegs are sometimes used instead of metal nails; but I

have found that ivory pegs are not so easily removed as iron nail as the outer surface becomes rough from contact with the tissue especially bone. The ivory pegs become decalcified by the action of the carbonic acid in the tissues, and the remaining organic portion is dissolved, thus producing small pockets and cavities into which the surrounding bone grows. The aseptic nailing together of the surfaces of a wound in bone, as after resections, particularly of the knee and ankle, in fractures, separation of the epiphyses, etc., is entirely devoid of danger if the operation is performed with the strictest antiseptic precautions.

For fastening together a divided bone, as in separation of the epiphysis at the upper end of the humerus, Helferich has recommended long, awl-like steel needles, fitted with a handle which unscrews. These are made to slowly bore their way into the bone. After eight to fourteen days the needles are removed.

Special clamp apparatus have been devised for uniting bone surfaces (Gussenbauer, Parkhill). Screws may, for example, be inserted into both fragments, and the two projecting ends of the screws connected by some form of clamp. Under fractures we shall become acquainted with Malgaigne's hooks and Langenbeck's screw. In cases of fracture Bircher has recently introduced the practice of inserting an ivory peg into the open ends of the medullary cavity of the diaphysis, and of using ivory clamps for holding in contact fractures involving the epiphyses. In part of the cases the wound healed up over the ivory peg; in sixteen cases (out of thirty-five) the peg had to be subsequently extracted.

Fig. 111.—Union of the ends of bones by implantation.

Another method of uniting bone surfaces is illustrated in Fig. 111. The somewhat pointed extremity of one fragment (the femur) is inserted, for instance after resection of the knee, into the medullary cavity of the other fragment of bone (in this case the tibia).

The treatment of defects in bone is described in § 43 and § 101.

CHAPTER IX.

AMPUTATIONS, DISARTICULATIONS, AND RESECTIONS.

Performance of amputations and disarticulations.—Subperiosteal amputations and disarticulations.—History of the methods of amputation and disarticulation.—After treatment.—Bad sequelæ.—Infection of the wound.—Muscular spasm.—Secondary hæmorrhage.—Gangrene of the flaps.—Necrosis of the stump of the bone.—Conical stump.—Neuralgia.—Neuromata.—Fatal results.—Mortality statistics.—Artificial limbs.—The methods of performing resection.

§ 35. **General Considerations in performing Amputations and Disarticulations.**—By *amputation* (from *amputare*, to cut off) is understood the operative removal of an entire portion of an extremity. If a limb is severed through a joint the operation is called a disarticulation, in contradistinction to amputation, in which the portion of the limb removed is cut off by sawing through the bone in its continuity. Amputation is not confined to the extremities alone, but is used to designate the removal of certain portions of the trunk, like amputation of the breast, the penis, or the cervix. We shall discuss here only amputations and disarticulations of the extremities.

The Indications for Amputation and Disarticulation have markedly decreased in modern surgery, which leans more and more towards conservative methods of treatment. With the aid of the antiseptic methods we are now often able to save a limb which formerly, in the preantiseptic era, would have fallen a prey to the mutilating effects of amputation and disarticulation. We shall entirely omit a detailed description at this point of the indications for amputation and disarticulation, as there will be opportunity enough for discussing this subject when we take up special diseases and injuries. It is sufficient to state here that these operations are indicated in all diseases and injuries of the extremities which threaten to destroy the whole limb or the life of the patient, and hence in (1) extensive injury to the soft parts and bone which precludes the possibility of saving the extremity in question, or renders the physical condition of the patient such that he cannot withstand long confinement to bed, or in consequence of which the extremity, if spared, would be useless; or (2) in extensive inflammation or disease of the extremity which would render it completely incapable of performing its functions, or which threatens the life of the patient. Under the latter heading come extensive gangrene, malignant new growths, irreparable injuries

to bones and joints, large ulcers, spreading (septic) intermuscular suppuration with threatening systemic infection, etc. Under the separate injuries and diseases we shall refer again to the indications for amputation and disarticulation. At present the general suggestions just made will be sufficient.

When an *amputation* and when a *disarticulation* should be performed are questions which in general depend upon the nature of the case in hand and the location of the injury or disease. We shall discuss this more fully in the Regional Surgery. Formerly, in the pre-antiseptic days, disarticulation was performed more frequently, as it dispensed with the dreaded opening of the medullary cavity. In fact, there were surgeons who went so far as to give up amputations for this reason and performed only disarticulations. Since the introduction of the aseptic method of operating this consideration is no longer thought of. At present the question whether amputation or disarticulation is better for any particular case is usually decided by practical considerations. Both forms of operation are practised, and amputation or disarticulation is decided upon according to the circumstances in each individual case. In general, amputations are performed much more frequently than disarticulations, because the former can be carried out at any part of the extremity; while the latter are confined to the joints.

The method of dividing the soft parts, particularly the skin, is practically the same in both operations. The soft parts must be divided in such a way as to form a good covering for the bone stump. We distinguish three principal forms of incision—(1) the circular, (2) the flap, and (3) the racket-shaped incision.

§ 36. **General Considerations in regard to Amputations.**—The field of operation is carefully cleaned throughout its whole extent with soap and a brush, shaved, and then disinfected with a three- to five-per-cent. solution of carbolic acid or 1 to 1,000 bichloride. The patient is placed in a convenient position, and a particular duty is assigned to each assistant. The operator stands so that the limb to be operated upon will fall to his right. We operate in all cases, if possible, with the assistance of Esmarch's artificial ischæmia, described in § 19. During the operation all the rules of antisepsis must be strictly observed by the operator and his assistants; no unclean finger or instrument should come in contact with the wound. The knife as well as the saw should be used carefully and gently, and care should be taken not to bear down too hard on the instruments. Violent manipulation and compression of the soft parts are to be avoided, as well as too vigorous rubbing of the wound with sponges or compresses. In fact, sponging can be almost entirely dispensed with when Esmarch's artificial ischæmia is used.

lar Division of the Soft Parts by a Single Stroke (Celsus, ıe soft parts, having been drawn up by the hands of an re divided circularly down to the single stroke of the amputation 112) held at right angles to the limb (Fig. 113). The size of the knife should depend upon the the limb. The knife is grasped d fist, the hand passed under the he incision is begun with the part nearest the handle, which is placed rtion of the surface of the limb s the operator (Fig. 113). The n drawn around the entire circum- he limb, dividing all the soft parts e bone. I think it is easier and egin the incision with the knife in ıgled position, point upwards, on the limb which faces away from r. The knife is then carried with otion around about two thirds of erence of the limb, dividing all the lown to the bone. Starting from ng of this incision, the knife is car- reverse direction, dividing the soft ıe side of the limb facing the operator. After division of rts the bone is sawed through. Then the cylinder of the soft parts is drawn up on the bone stump by an assistant, while the operator grasps the extremity of the bone stump with Luer's or Langenbeck's bone forceps (Figs. 83, *d*, and 85), and elevates or pushes back the periosteum by means of a periosteal elevator (raspatory, Fig. 79) a ıal to about half the diameter of the limb. At this point again sawed through, thus allowing the cylinder of soft

Fig. 112.—Amputation knives.

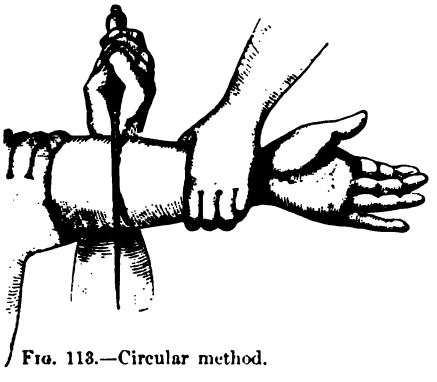


Fig. 113.—Circular method.

parts to completely cover the stump of bone and the edges of the skin to be united, usually in a transverse line, without tension on the sutures. This separation of the periosteum is really unnecessary, and I regard it as a useless complication of the operation. It is simpler to dissect off the muscle from the bone on all sides, or to cut out a cone in the muscles before sawing through the bone. In amputations of extremities containing two bones, such as the leg, the forearm, the metacarpus and metatarsus, the muscles and soft parts lying between the bones must be divided before sawing the bones. For this purpose a small, pointed, double-edged knife, sometimes called a catline, is best (Fig. 114). This knife is inserted in the space between the bones and the soft parts are divided by cutting first with one edge against one of the bones and then with the other edge against the other bone. This procedure is then repeated by inserting the knife from the opposite side into the space between the bones. Instead of the two-edged knife, a small scalpel can be used for this purpose. After dividing the soft parts in the space between the bones and laying the bones free, the latter are sawed in such a way that the division of both is completed at the same time. Thus, in amputations of the leg the tibia is first sawed about three quarters through before one begins to saw the fibula, and then both are completely sawed through at the same time.

Fig. 114. Catline.

For sawing the bones in amputations it is best to use the bow saw (see page 88, Fig. 86, *b*, *c*) in the way illustrated in Fig. 115—i. e., the saw is placed close to the soft parts, at right angles to the thumb of the left hand, which is placed upon them. To prevent injury to the soft parts they are retracted by a split aseptic compress (Fig. 116) or the hand of an assistant. The distal portion of the limb is held by an assistant, and allowed to drop a little as the sawing progresses, so that the saw does not become jammed. If projecting spicules of bone remain after the sawing is completed they must be cut or smoothed off by bone shears or forceps, or the metacarpal saw or chisel may be used for this purpose, as for removing the anterior projecting border of the tibia.

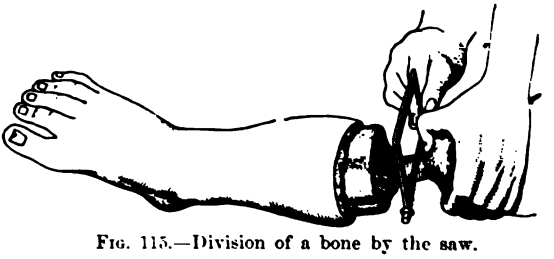


Fig. 115.—Division of a bone by the saw.

On account of the rapidity with which it could be done, the circular method, performed with one sweep, used to be much employed when operations were carried out without anæsthesia, but at the present time it is less often used. In fact, it is little suited for extremities having powerful muscles, for it provides a more or less insufficient covering of soft parts and of skin for the bone stump, and therefore is conducive to the formation of the so-called conical stump. But, on the other hand, this method is a perfectly proper one for performing amputations on children and thin subjects, particularly in the case of limbs containing only one bone.

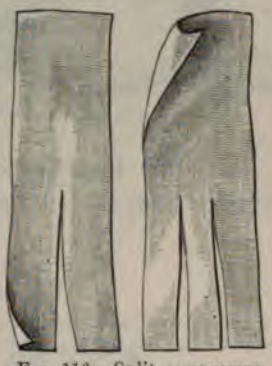


Fig. 116.—Split compresses.

II. **Circular Method of dividing the Soft Parts at Two Different Levels.**—An incision is carried circularly around the limb through the skin down to the fascia. The skin is then drawn up by an assistant, while it is freed from the subjacent parts by carrying a knife, held at right angles to the axis of the limb, circularly around the latter at the edge of the skin, cutting down to the fascia (Fig. 117), or by dissecting the skin and subcutaneous tissue from the deeper tissues by means of a scalpel. When the skin has been thus sufficiently freed from the fascia it is turned back in the form of a cuff, the length of which should equal about half the diameter of the limb. A circular incision through all the soft parts down to the bone is then made close to the attached edge of the cutaneous cuff, and the bone is then sawed in the manner already described. Here also it is a good plan to separate the muscular insertions from the bone for a short distance to insure a sufficient covering for the stump.

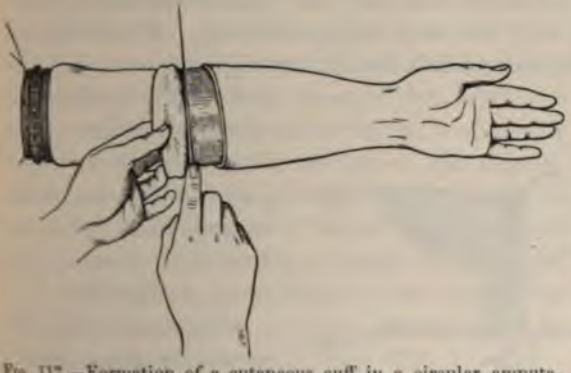


Fig. 117.—Formation of a cutaneous cuff in a circular amputation at two levels.

Funnel-shaped Method.—The so-called funnel-shaped method of dividing the soft parts (Alanson) is only a modification of the method just described. The skin is first divided circularly, and the knife is then

applied at the margin of the retracted skin, having its edge directed obliquely upwards and at the same time towards the bone, in which direction it is carried through the muscles down to the bone. In this way a conical-shaped wound surface is made, with its apex towards the upper end of the bone.

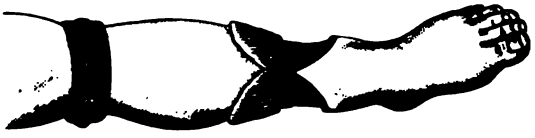


FIG. 118.—Formation of two semilunar skin flaps.

III. **The Flap Methods.**—The flap methods vary in the thickness, shape, and length of the flaps. At the present time flaps are generally made to consist only of skin, or skin and subcutaneous tissue, as it is well known that the muscles in the flap covering the bone stump subsequently disappear entirely by fatty degeneration. But it is an excellent plan to fashion flaps of both cutaneous and muscular tissue whenever the skin is very thin and badly nourished. The shape and position of the flaps vary very much, though anterior and posterior flaps are usually made either of equal length, or a long anterior and short posterior flap are made, in order that the suture line shall come to lie more posteriorly.

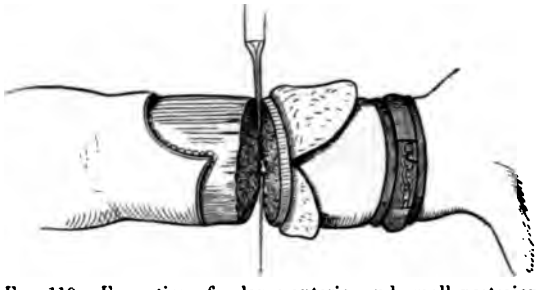


FIG. 119.—Formation of a large anterior and small posterior skin flap.

The incision for the cutaneous flaps may be made in the same way as in the circular method of amputating in two stages just described, and then longitudinal incisions some five or six centimetres long are made on the inner and outer aspect of the extremity, thus forming two cutaneous flaps of equal length, an anterior and a posterior. These

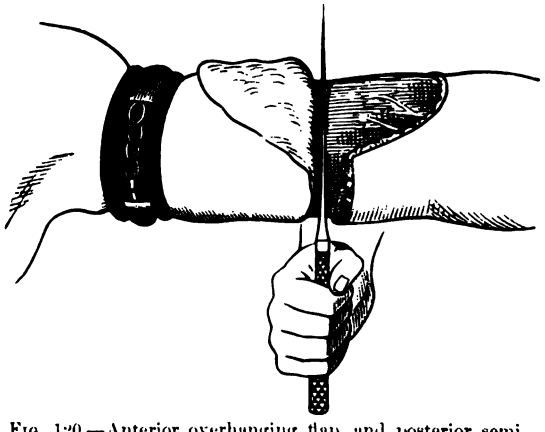


FIG. 120.—Anterior overhanging flap, and posterior semicircular incision.

are then freed from the fascia and turned back. The muscles are divided at the point where the cutaneous flaps are turned back, just as in the circular method of amputating in two stages. Another way is to form two semilunar-shaped skin flaps, either in front and behind or laterally, using a large scalpel with a blade convex on the edge. The flaps of skin are dissected from the fascia and turned back (Fig. 118).

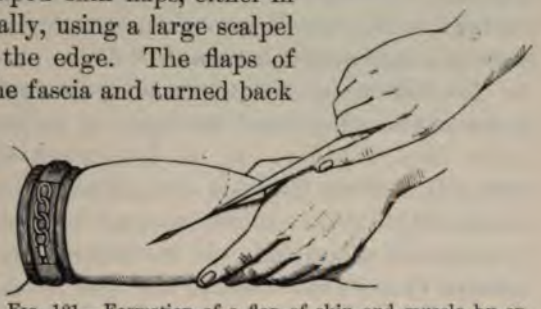


Fig. 121.—Formation of a flap of skin and muscle by an incision from without inwards.

Another good plan is to make a long, semilunar-shaped anterior flap of skin with a small posterior flap (Fig. 119). The former must be long enough to cover the entire cut surface like a curtain. The overhanging anterior flap is made in the simplest way, by cutting an anterior semilunar-shaped cutaneous flap and freeing it from the subjacent parts. The base of the flap should be equal to about half the circumference of the limb, and its length should equal its sagittal diameter. A similar but smaller cutaneous flap is then cut from the posterior half of the circumference of the limb and dissected from the fascia.

A very simple way of carrying out this method of amputation by a long anterior flap, after the latter has been cut and turned back, is to divide the skin on the posterior portion of the circumference of the limb by a single circular sweep of the knife. The posterior flap is then dissected back from below upwards, as usual, by strokes of the knife held at right angles to the axis of the limb, and the muscles are then cut circularly by a single sweep of the knife (Fig. 120).

Fig. 122.—Disarticulation of the middle finger: 1, extensor tendon; 2, flexor tendon and near by the two ligated digital arteries and the nerves. In the centre of the wound is seen the articular surface of the metacarpus.

Some surgeons prefer to include the fascia in the skin flaps, freeing skin and fascia together from the underlying muscles, as they believe that the skin flaps are better nourished in this way by the extensive network of vessels lying between the skin and fascia, particularly if the portion of skin in question is loosely attached and thin. I do not like these flaps of combined skin and fascia, and agree with Oberst that the fascia, on account of its poor blood supply, especially if the conditions for cir-

culation are unfavourable, is liable to necrose and so interfe primary union. I think it better to form cutaneous flaps wit fascia. If the skin is not suitable for making flaps on account too thin, I prefer the circular method of amputation, carrying t to the bone in one sweep, or the method in which the flaps both skin and muscular tissue.

The formation of flaps consisting of both skin and muscul is not at present so much in vogue as formerly. The wound is too large, the flaps are too heavy, and the vessels are usu obliquely. These flaps are formed either by cutting from wit wards (Fig. 121), or in the reverse direction, from within o by means of transfixion. In the latter method a double-edged inserted close to the bone, at the base of the flap to be forme the knife is carried with a sawing motion obliquely downwa outwards. All transfixion methods are bad, because the ve often wounded or divided in two different places. It was f used very often, when operations had to be performed rapidly anæsthesia.

IV. **The Oval or Racket Incision** (Fig. 122).—This is a com between the single circular sweep of the knife and the flap It is chiefly used for disarticulating fingers and toes, but it i made use of in amputating. It is really an obliquely place lar amputation—i. e., two la cisions are made, which m sharp upward angle on the the limb, and in a slight do curve on the front.

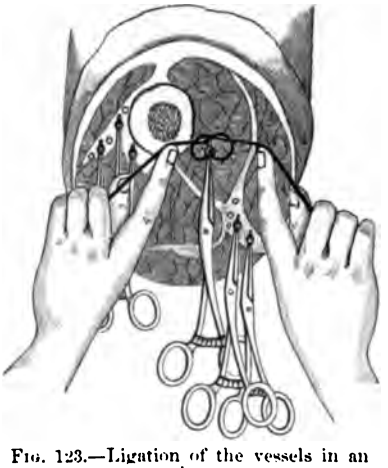


Fig. 123.—Ligation of the vessels in an amputation stump.

The Treatment of Am Wounds.—Hæmorrhage afte tation is arrested by seizi rately all the divided vess arteries and veins, in the l stump with self-locking hæ clamps and then ligating th catgut or aseptic silk (Fi To find the small muscular l in the surface of the bloodles one should follow the musc terspaces, where the vessel discovered and grasped with clamps. If any vessel cannot b out or isolated, it should be secured by passing a sharply curve carrying a catgut suture through the soft parts around the

vessel (page 98, Fig. 95). The suture is then tied so as to include the soft parts and the vessel. Small vessels can be closed by torsion, as described in § 28. After all the vessels in sight have been ligated, the Esmarch elastic tourniquet is removed, while the amputation wound is elevated and pressure exerted upon it by aseptic sponges. Pressure lasting a couple of minutes is the best means of arresting the ensuing parenchymatous hæmorrhage, which is very apt to be considerable immediately after the removal of the Esmarch tourniquet, on account of the vasomotor paralysis that it causes.

When the hæmorrhage has been very carefully arrested the large nerve trunks are drawn out of the wound and cut off with scissors, to prevent the possibility of any subsequent neuralgia or the formation of amputation neuromata. After this the wound is disinfected, together with the parts surrounding it, by irrigation with a 1 to 1,000–5,000 bichloride solution, or a three-per-cent. solution of carbolic acid, suitably drained, and its margins are united by sutures. If the asepsis has been perfect throughout, there is no necessity of antiseptic irrigation of the wound, as this only causes irritation and increases the subsequent discharge from the wound. It is sufficient to wash out the wound with a sterilised seven-tenths-per-cent. solution of common salt or simple warm boiled water. The drainage tubes are fastened to the skin by a suture, one tube being generally placed in the posterior flap, and, when necessary, others are placed in the angle of the wound at each side (§ 31). The wound is closed (§ 33) by inserting several interrupted tension sutures and then a continuous catgut suture. Great care must be taken in inserting the sutures. They should be even, and hold the margin of the wound in perfect apposition. All drawing and tension must be avoided. Neuber recommends the use of several rows of sutures for closing an amputation wound. He sutures first the periosteum, then the muscles, and finally the skin, and thus avoids the formation of any pockets. According to my ideas, this form of suturing is unnecessary and even bad, and I have found that an aseptic dressing, applied so as to exert suitable pressure, is entirely sufficient to prevent the formation of pockets. Credé dispenses with both drainage and suturing in amputation wounds, and obtains primary union simply by compression of the wound with the dressings. I have tried this method and found it very satisfactory.

An *aseptic protective covering* which exerts moderate pressure is the most suitable form of dressing for amputations. The stump, after application of the dressing, is placed in a slightly elevated position, and left for the time being uncovered, so that any secondary hæmorrhage may be recognised at once.

Subperiosteal Amputations.—Ollier, particularly, has upheld subperiosteal amputations, reasoning from the results obtained from experiments made on animals. He makes a flap from the periosteum to promote primary union of the deeply lying parts, and to prevent inflammatory complications from occurring in the medullary cavity. But when this method is used on man the results are not so good as the experiments on animals would seem to indicate. At present Cllier has himself given up periosteal flaps, and even considers them harmful in children, on account of the tendency to form osteophytes. Bruns has recently recommended the employment of the subperiosteal method for amputation of the leg. It possesses the advantage here of preventing gangrene of the flaps. Subperiosteal disarticulations can be highly recommended (see Disarticulations). In order to obtain a stump that would support better the weight of the body Bier used to make an artificial foot by turning up the end of the tibia (see Regional Surgery), and for the same purpose he now covers the wound surface with a pedunculated periosteum bone flap from the tibia (see Regional Surgery). The stump of the tibia may also be covered with a flap from the fibula (Lanz).

Amputation, with Scraping Out of the Diseased Medullary Cavity.—In diseases of the marrow of bone, such as suppurative osteomyelitis, König and Stoll have performed amputation accompanied by scraping out the marrow, and have obtained good results. In this way disarticulation at the joint above can be avoided.

§ 37. **The Method of performing Disarticulations.**—The technique is in the main the same as for amputations. The method by circular incisions at two levels, with turning back of a cutaneous cuff, can be used, or flaps may be cut of skin, or skin and muscular tissue combined.

In disarticulations, a long anterior overhanging flap and a small posterior one are much used, and are made as described above (Figs. 119, 121). In disarticulations at the ankle or medio-tarsal joint, or of the fingers or toes, the posterior flap can be make the larger. For disarticulation at the small joints of the fingers or toes, especially the metatarso- and metacarpo-phalangeal joints, the racket incision is very often used (Fig. 122).

After dividing the overlying soft parts in the form of skin flaps, or flaps of skin and muscular tissue combined, or after making the circular incision in two stages and turning back the cutaneous cuff, the ligaments of the joint are made tense and the joint opened. Whenever it is necessary, any prominent part entering into the formation of the joint can be cut away; and it is sometimes best to extirpate the synovial membrane completely, in order to obtain a wound surface to which the cutaneous flaps may unite more rapidly. The details for performing disarticulations are, in general, precisely similar to those for amputations.

For the method of performing disarticulation on particular joints, as well as the various amputations, the reader is referred to the textbook on Regional Surgery.

Subperiosteal Disarticulation.—Ollier, especially, has recommended the regular use of subperiosteal disarticulation. Ollier's description is as follows: The same incision is made as for resection of the particular joint in question (see § 40), dividing at the same time both capsule and periosteum. By means of a raspatory the periosteum is elevated from the bone and pushed aside from the joint, together with such muscular insertions as are present; the head of the bone is then enucleated, and the soft parts cut transversely to the axis of the limb. Extensive new formation of bone has been observed after subperiosteal disarticulation, not only in animals, but also in man in early life. This is especially true of subperiosteal disarticulation and amputation through the upper end of the metatarsus or metacarpus, and also after disarticulation at the tibio-tarsal joint with preservation of the periosteum of the os calcis. New bone has been seen to develop within the hip joint after subperiosteal disarticulation of the head of the femur. This new bone was movable within the joint and gave support to the stump. The subperiosteal and subcapsular shelling out of the bone is probably of most use in cases of disarticulation for gunshot injuries.

History.—During the middle ages and until the close of the sixteenth century amputations were done in the most horrible ways, on account of the inefficient methods then in vogue for arresting hæmorrhage, and usually ended fatally. The bleeding was checked by encircling the member to be operated upon with a strong rope, or the red-hot iron was used; boiling oil was poured over the wound, or the operation was performed with red-hot knives. Permanent constriction of the limb and caustics were also sometimes used. The technique was very greatly advanced by the introduction of the ligature of vessels by Ambrose Paré and his followers (1659–1692), and after this by the invention of the tourniquet by Morel (1674). The ligature of vessels for arresting hæmorrhage had been well understood by the surgeons of antiquity, and was in general use in the time of the Roman Empire. The ligature was afterwards entirely forgotten, as has been mentioned, and was later rediscovered by Paré.

In more recent times amputation was occasionally performed by the écraseur (Chassaignac), the galvano-cautery (Bruns), and the elastic ligature (Dittel). But now all these methods have become simply matters of history since the introduction of antiseptics.

§ 38. **The After-treatment of Amputations and Disarticulations.**—The after-treatment of amputations and disarticulations is very simple if no fever occurs and the wound runs a normal course in healing. The first dressing should not be disturbed till the time arrives for removing the drains—i. e., till the second, third, or fourth day, according to the size of the wound. Some of the stitches are also taken out at the same time. Then the second dressing is applied, and it is often the last. If fever occurs, or if the patient complains of pain, the dressing should be changed earlier.

For the details of treating the patient who has been operated upon, reference is made to § 22.

Bad Results.—Since the introduction of the present antiseptic method of operating and treating wounds the immediate bad results which have been observed to follow amputations and disarticulations are infrequent. It is generally expected that healing will take place without any reaction. The occurrence of wound infection—such as suppuration, pyæmia, septicæmia, erysipelas, and osteomyelitis, so frequently observed in the preantiseptic period—is now exceptional, and only takes place when an extremity is operated upon which is already infected, or when the rules of asepsis are not rigidly adhered to. For the treatment of these diseases of wounds resulting from infection, as well as for the treatment of shock, delirium tremens, etc., reference is made to § 62 to § 75.

Among the other immediate bad symptoms after amputation we may mention the occurrence of cramps or violent contractions of the muscles in the stump. These are liable to come on soon after the operation, and are best treated by subcutaneous injections of morphine and by fixation of the stump by means of light sand-bags, etc. (See also § 64, Delirium Tremens.)

Secondary hæmorrhage also occurs much less frequently than it formerly did, because we have learned to take great pains to arrest all bleeding during the operation. Secondary hæmorrhage starts either from an unsecured vessel which had retracted at the time that the bleeding from the stump was being stopped, or from a vessel which had been tied off but had opened again. In such cases of secondary hæmorrhage from an artery often nothing but the reopening of the wound and the securing of the bleeding vessel will suffice to check it. The best way of treating parenchymatous secondary hæmorrhage or oozing is to apply an aseptic dressing in such a manner as to exert proper pressure and to place the stump in an elevated position. At a later stage in the process of healing it is still possible for secondary hæmorrhage to occur from perforation of the wall of the vessel resulting from suppuration when the wound does not heal by primary union. The treatment of this is also practically the same—i. e., the hæmorrhage should be stopped by applying a ligature at the point from which blood issues.

If the skin is very thin, or if the skin flaps lie upon a non-vascular surface like cartilage, as is the case in disarticulations, or if the dressings are applied so as to exert too much pressure, there is apt to be a more or less extensive death or gangrene of the flaps. In such cases one must either await the separation of the damaged portion of the flap, or, if the gangrene is too extensive, a higher amputation must be performed. The gangrene is sometimes due to constitutional causes (diabetes, arteriosclerosis, etc.).

Sometimes necrosis occurs in the stump of the bone, especially if there has been suppuration. Under these circumstances one must wait until the sequestrum has become loosened, and then remove it. The bone stump does not necrose if the wound heals normally and without reaction.

Another bad result after amputation is the so-called conical stump. This may be the fault of the method of operating—i. e., the cutaneous flaps were made too short for sufficiently covering the bone stump, or it may be due to the death of part of the cutaneous flaps, or to retraction of the soft parts as a result of suppuration. This latter cause was relatively common in the preantiseptic period of surgery. At present conical amputation stumps are rare, and are usually the result of an unskilful performance of the operation. In rare cases a conical stump, particularly after amputation of the upper arm and the leg, may occur in young individuals from longitudinal growth of the bone at the upper intact epiphysis. Poncet observed in one case a growth of eight centimetres in three years. In a well-marked conical stump the end of the bone projects from the soft parts through the granulating surface of the wound, and either cicatrisation does not take place, or the slowly forming, adherent scar is so tense and sensitive that the use of the stump and the wearing of an artificial limb are impossible. Under such conditions there is nothing to be done but to perform a reamputation or a subperiosteal resection of the bone. The latter is best carried out by making a longitudinal incision through the soft parts and periosteum down to the stump of bone, care being taken to avoid large vessels and nerves; the periosteum and the overlying soft parts are then separated by means of the raspatory and periosteal elevator from the bone, and a sufficiently long piece of bone is removed with the saw or hammer and chisel.

Since the era of aseptic surgery, the neuralgia of the amputation stump which used to occur after suppuration is seldom observed. The pain is caused in some cases by cicatricial contraction following suppuration and resulting in constriction of the ends of the nerves, and in other cases the enlarged ends of the nerves become adherent to the bone or the superficial layer of the stump. The ends of the nerves usually show a club-shaped enlargement (amputation neuroma). The latter consists of connective tissue with more or less numerous bundles of newly formed nerve fibres. The formation of these amputation neuromata, which sometimes cause very severe pain, is best prevented by aseptic healing and by drawing out the ends of the large nerves with forceps after every amputation and cutting off a considerable portion with scissors, in order that the nerves may retract well between

the muscles. Moreover, great care should be taken not to include nerves in the ligatures placed on the vessels. The treatment of neuralgia occurring in a stump consists in the excision of a long piece of the affected nerve trunk (neurectomy), and in the extirpation of any neuromata which may be present.

During the first few days or weeks many patients who have undergone an amputation complain of pain of greater or less severity referred to the amputated part, which, however, gradually disappears in the great majority of cases. On account of irritation of the ends of the sensory nerve fibres which originally supplied the fingers or toes, these patients feel pain in those parts though they no longer possess them. The sensations referred to the portions of the extremities which no longer exist last a variable length of time—often a year—and patients are very likely to dream that they still have their lost limb.

Death following Amputation and Disarticulation.—A fatal result following amputation or disarticulation is either caused by one of the forms of wound infection, such as septicæmia, pyæmia, erysipelas, or tetanus, or by collapse, by anæmia from great loss of blood, by secondary hæmorrhage, delirium tremens, fat emboli, or other intercurrent diseases. In general, age does not play so important a part in the prognosis of amputations and disarticulations as it formerly did, because we have learned how to avoid loss of blood, and healing is more rapid with the aseptic method of operating. It often happens in old people that there is marked atheromatous degeneration of the arteries, and yet the wound will heal satisfactorily. Furthermore, syphilis, tuberculosis, and kidney disease have no such deleterious effect on healing as was formerly believed. In every case the prognosis after an amputation is favourable if there are no complications, and if there has been no transgression of the rules of antisepsis.

Mortality of Amputations.—The mortality of aseptic amputations varies with the nature of the case and the presence or absence of complications. According to Oberst, of 260 uncomplicated amputations 14 died, a mortality of 5.4 per cent.; but, on the other hand, there were 39 deaths in 91 cases where complications were present, a mortality of 42.8 per cent. Of 57 amputations in which sepsis was already present, 40 recovered, and, taking all cases without distinction, Oberst collected 351 amputations with 53 deaths, or a mortality of 15.1 per cent., and 84.9 per cent. recoveries. Wölfler has given the total mortality of amputations occurring in Billroth's clinic as 19.7 per cent. In uncomplicated cases the mortality was 5.7 per cent., and in those in which complications occurred—i. e., in amputations where sepsis and pyæmia were already present—the mortality was 43.7 per cent. Essen (in Wahl's clinic) gives the total death rate as 17.9 per cent., the mortality of uncomplicated cases being 5.93 per cent., and of those with complications 42.8 per cent. The mortality of the 255 amputations performed in Czerny's clinic was only

2.7 per cent. (Schrade). The decrease in the mortality is to be ascribed solely to the aseptic method of treating wounds, and the mortality of amputations and disarticulations would be still less if all the operations could be performed immediately after the injury.

§ 39. **Artificial Limbs.**—The substitution of artificial limbs for lost extremities has become more and more common in recent years. In the case of the lower extremity, the prothetic apparatus need only render standing and walking possible, and consequently it is conceivable that more satisfactory results can be obtained here than in the upper extremity, where the manifold movements of the hand and fingers can be only partially supplied; and not every one is in a position to pro-

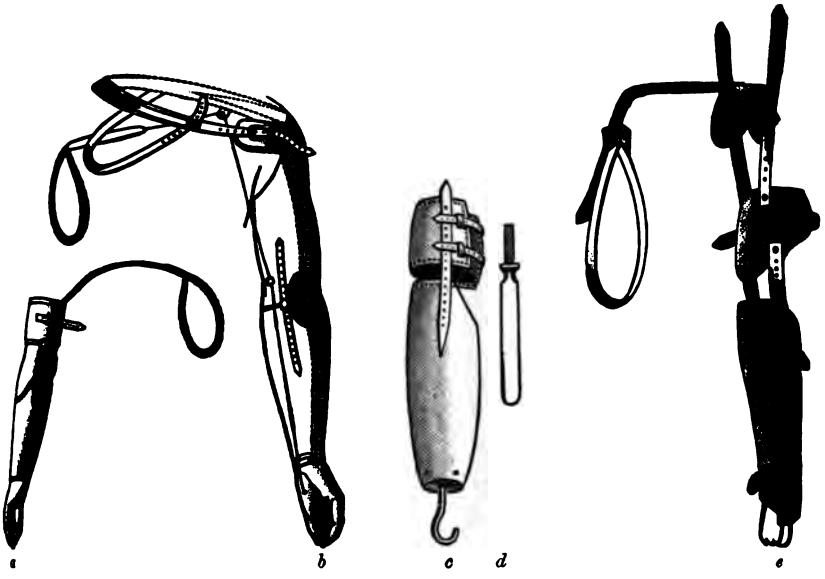


Fig. 124.—Artificial limbs for the upper extremity: *a*, for the forearm; *b*, for the upper arm; *c*, *d*, and *e*, limbs with different kinds of insertion pieces.

vide himself with such costly apparatus as artificial arms and legs, with their complicated mechanism. As to the upper extremity, the movements of the fingers are usually imitated by spiral springs, or springs are placed in the apparatus in such a way as to make the latter movable when manipulated by the other hand or pressed against the thorax by the stump, etc. The simplest and cheapest prothetic apparatus for an amputated arm or forearm consists of a leather socket in which the stump is placed and retained by straps. The artificial hand should be arranged so that it can be taken off and replaced by a hook, a knife, or a claw (Fig. 124, *c*, *d*, *e*). It is remarkable how much some patients can sometimes accomplish with such a simple apparatus.

After amputation or disarticulation of the lower extremity we ma use either of the peg leg (Figs. 125 to 127) or the artificial limb (Fi 128, 129). The peg leg is the cheaper and by far the simpler ap ratus, and with it walking is generally easier and more comfortal than with the artificial limb. Many who have long been torment by the latter turn finally to the use of the peg. And it is worth taki into consideration that the peg leg can be repaired by any mechar while the artificial limb requires a skilled instrument-maker. Tren lenburg and others have shown that the peg leg can be improvi very cheaply by fastening a stick of wood to a socket made of pa

Fig. 125.—Peg leg for amputations below the knee.

Fig. 126.—Peg leg for amputations at the knee.

Fig. 127.—Peg leg for amputations of the thigh.

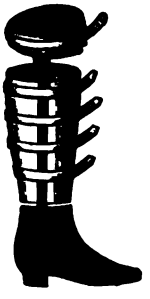


Fig. 128.—Artificial foot.

Fig. 129.—Artificial for disarticulation the hip, or high putation of the th

board by means of a water-glass bandage. The artificial leg is usua made of a leather pocket in which the stump is placed; to this is joir the leg, which is made of wood, having hinges for the knee and an joints. The foot can be extended, when pressing against the grou by means of a strong spiral spring. The movement of the knee jo is accomplished by some elastic material placed inside the leg simulating the function of the muscles. If only a part of the foo lost the defect can be concealed and walking rendered possible by p ding an ordinary boot with cotton. Some artificial legs are made v a rubber foot.

These brief remarks will suffice for a general understanding of the principles of artificial limbs.

Crutches.—Crutches must be well padded, as otherwise they may give rise to so-called crutch paralysis from pressure on the nerves in the axilla.

§ 40. **Operations on Joints.**—By *resection* of a joint is meant the partial or complete operative removal of the opposed bony surfaces forming the joint by means of the saw, sharp spoon, or chisel. A distinction is made between partial and complete resection, depending upon whether the ends of the bone are completely or only in part removed. If the joint is extensively diseased, we do not satisfy ourselves with removal of the bony portion, but also extirpate the synovial membrane—i. e., we perform a complete extirpation of the joint. In all cases in which the periosteum is healthy we preserve it on account of its osteoplastic power, and call a resection of this kind subperiosteal. A distinction is made between early and late resection and between primary, intermediate, and secondary resection. By primary resection is meant one which is performed immediately after the traumatism has occurred and before the onset of inflammatory reaction. The intermediate resection is performed after inflammatory symptoms appear. A secondary resection is one performed after the subsidence of the inflammatory reaction, when the wound is granulating.

Resection of Bones in Continuity.—Furthermore, we resect bones in their *continuity* when we remove greater or less amounts of diseased portions of them by means of the chisel or saw. The removal of diseased bone by the sharp spoon—for example, in tuberculosis—is designated as a scraping out, while the simple division of bone in its continuity is called osteotomy.

Arthrectomy.—If the bony parts forming the joint are left intact, and only the diseased synovial membrane of the joint is removed, as in tuberculosis, the operation is an arthrectomy. The simple opening of the joint is called arthrotomy. We shall confine ourselves here to the general technique of joint resections, and shall take up the resections of particular joints in the Regional Surgery.

Indications for Resection of a Joint.—The *indications* for resecting a joint, especially for performing total resection, have become much fewer in number since the introduction of antiseptic surgery. At the present time we are often able to save a joint—one, for instance, which has been laid open by a wound—where formerly it would have been sacrificed. We now go on the principle of performing a resection as conservatively as possible—i. e., we try to preserve as much of the articular surfaces of the bone as we can. The complete resection of joints in children, which used to be so frequently performed for tuberculosis, should be entirely given up. In these cases we

should be satisfied with removing the diseased portion of the bone with the sharp spoon or the chisel, with the single exception of the hip joint; and in adults the use of total resection should be restricted as much as possible, and as much bone saved as possible. If only the capsule of the joint is diseased —as, for example, in tuberculosis—only this should be extirpated (arthrectomy), and the bony portion of the joint should be left intact. When arthrectomy is performed—for instance, at the knee in the case of synovial disease—a movable joint may be obtained (Angerer, Sendler, myself, and others). On the other hand, it cannot be denied that a very good functional result is possible after an extensive atypical resection, as in the case of the foot, and amputation be thus avoided. I agree with Kappeler, Mikulicz, Küster, and others in sanctioning extensive atypical resections, particularly of the foot.

In general, resection of a joint is indicated after severe injuries (traumatic resection) and for pathological changes in the joint (pathological resection). Among conditions in a joint calling for resection are (1) compound fractures involving the joint, with considerable splintering of the bones, especially gunshot fractures; also dislocations accompanied by rupture of the skin and overlying parts. Since the introduction of antisepsis it will often be found sufficient in these cases to drain the joint thoroughly after reducing the dislocation or removing whatever loose fragments are entirely detached. Resection of a joint is also called for (2) when there is very extensive suppuration or violent inflammation in the joint after an injury, and especially when there is (3) chronic disease of the joint, tuberculosis being the most common. Resections may also be performed for (4) loss of function in a joint caused by contractures or anchylosis, and in old dislocations in which there is a malposition of the bones which interferes with the function of the joint, or in which the head of the bone presses on nerves and vessels, and, finally, (5) for new growths in the bones.

Osteoclasis, or subcutaneous fracture of bones by the osteoclast. (Mollière), has of late years been used very largely in place of the so-called orthopædic resections for improving deformities of bone. But I agree with Ollier, that osteoclasis is not always as effective as its inventor claims; and, furthermore, it is not always possible to break the bones at precisely the desired point and without damaging the soft parts. Osteoclasis cannot usually be employed in cases of anchylosis.

General Rules for performing Resection.—The operation of resecting a joint is divided into three stages: (1) The incision through the soft parts; (2) opening the joint; (3) division and removal of the injured or diseased ends of the bones with or without extirpation of the synovial membrane. When possible, the operation should be performed with the aid of Esmarch's artificial ischæmia, and of course with the strictest aseptic precautions. The soft parts are divided with a short, strong knife (Fig. 130). Resection knives are sometimes pointed, sometimes rounded, or blunt. The incision through the soft parts is made preferably in the long axis of the limb, because this involves the least injury to muscles and tendons at their point of insertion, as wel

s and nerves. Only in the case of the knee—and, under ıditions, the ankle—are transverse incisions allowable for better view of the diseased joint. The joint is opened in the cutaneous incision. It is very important for the future the joint to preserve the tendinous insertions of the mus- :he joint and to keep intact their connection, as well as that ule with the periosteum.

where the periosteum is in primary traumatic re- should be preserved— eriosteal resection should ıed. If it is diseased, it ırse be removed, as well e. If the periosteum is ned—that is, if we are o a subperiosteal resec- livided in the line of the ncision and raised by the Fig. 79) and periosteal ig. 80). At those places periosteum becomes con-

Fig. 180.—Resection knives.

:h the capsule, muscular insertions, and ligaments, it must ·d from the bone by perpendicular or horizontal strokes of

ıd König have introduced an excellent plan for retaining :ion of the muscular insertions to the bony protuberances to are attached. These protuberances are separated from the : bone by the hammer and chisel, or, in the case of children, fe, and at the conclusion of the operation they are again ck into place and secured by means of silver wire or nails. ɜ is a tubercular arthritis involving the whole joint, or when would of course be a mistake to preserve the periosteum. es the joint must be entirely extirpated—i. e., all diseased nd bone must be removed.

iosteum having been removed, or left in place, as the case : next step is the division of the bone (see § 26). The ends : are forced out of the wound, while the soft parts are held ractors, or the bony parts are divided *in situ* with the meta- , or chain saw, or with the chisel. The bones of children with the knife. After division of the bone all projecting evelled off.

/losis is desired—for example, in the case of the knee—the

ends of the bones are fastened together with catgut, silver wire, or four-cornered steel nails which have been carefully disinfected (see also § 34). Since partial resections give in general a better functional result than total ones, the former should be given, when possible, the preference in all joints in which we wish to obtain motion. The strictest asepsis must be maintained in all stages of the operation. At its conclusion the hæmorrhage must be arrested with the utmost care, drainage of the joint must be provided for, and, after suturing the wound and applying an antiseptic dressing, the joint must be immobilised by a suitable splint. If an Esmarch tourniquet is used, it can either be removed before inserting the sutures and the hæmorrhage stopped, or one can suture the wound, leaving the two angles open, apply an aseptic dressing, and then remove the tourniquet. I then apply a plaster-of-Paris splint over the aseptic dressing, and this is kept on for about four weeks. In order to diminish the secondary bleeding the extremity is elevated or suspended. In case of extensive suppuration of the joint, it must be thoroughly drained by tubes or gauze.

For the method of dressing individual joints after resection, reference is made to the text-book on Regional Surgery.

Outcome of Resections of Joints.—The results of joint resections are either anchylosis, or an actively movable joint, or a so-called flail-like joint. In the lower extremity, at the knee and ankle, anchylosis is the most desirable result. In the hip and upper extremity a movable joint is preferable. For restoring the function of a joint after the wound has healed, the after-treatment is of great importance. It is possible to obtain very excellent results by the methodical use of active and passive motion, by electricity, massage, and baths. If anchylosis is desired, the joint should be immobilised in the position which is most suitable for subsequent use, by means of a plaster dressing or a splint left in place for a considerable length of time (see Methods of Dressing, and Regional Surgery). If a flail-like joint is obtained, it must be re-enforced by a suitable supporting apparatus, or another operation must be done to obtain anchylosis (see Arthrodesis, below).

The *causes of death* following resection are, in the first place, the infectious wound diseases, such as sepsis or pyæmia, due to imperfect asepsis, or to their presence at the time of the operation. Furthermore, death may result from exhaustion due to the long confinement in bed, or from the underlying general disease, usually tuberculosis. Patients who have undergone this operation sometimes die from fat emboli, especially when there is advanced fatty degeneration of the bone marrow. Bones in which there is this fatty degeneration should not be joined together too closely.

History of Resections.—Resections were performed in the flourishing days of surgery at the time of the Roman Empire, but were forgotten entirely during the middle ages, and were not again systematically practised till near the close of the eighteenth century. In England, White was the first to use the operation, performing a resection of the humerus. In France the operation was employed by Moreau; later, by Sabatier, Percy, Dupuytren, and Larry. Textor, Jäger, and Ried introduced the operation among German surgeons. Langenbeck has done more than anybody to advance the technique of joint resection.

Arthrodesis.—By arthrodesis is understood the artificial anchylosis of a flail-like joint—in cases of paralysis, for example, for which it was first practised by Albert, who operated with excellent results on both knee joints of a young girl suffering from paralysis of the lower extremities. The operation is very useful, especially for paralytic flail-like joints. At first arthrodesis was frequently performed by fastening the bones together with a wire suture after a typical resection of their joint surfaces. But it is a better plan to merely scrape off the articular surfaces, leaving some of the cartilage behind, and then unite the bones with long, perfectly sterilised steel nails instead of the silver-wire suture. The synovial membrane should be allowed to remain intact. If healing takes place with some slight amount of suppuration, the synostosis of the joint ends of the bones is more solid than if the wound unites by primary union (Zinsmeister). H. Euringer has collected from literature 68 cases of arthrodesis (in 50 patients), of which the majority were successful, and enabled the patients to dispense with the heavy, uncomfortable, and expensive splint apparatus. Karasiewicz collected 87 cases (in 61 patients), of which 44 were performed on the ankle, 33 on the knee, and the others on the shoulder, elbow, hip, Chopart's, and the calcaneo-astragaloid joints. The results were good (bony union) in 59 cases, satisfactory (fibrous union) in 25, and bad in 3.

Arthrolysis.—Arthrolysis, or anchylolysis, is the opposite of arthrodesis. It consists in open division of all bands and adhesions both inside and outside the joint which interfere with its movement. The joint surfaces are not resected, and in this way an anchylosed or contracted joint may become movable again.

CHAPTER X.

OPERATIONS FOR REMEDYING DEFECTS IN THE TISSUES.—PLASTIC OPERATIONS.—TRANSPLANTATION.

Plastic operations for loss of substance in the skin.—General methods of plastic surgery in case of loss of substance in the skin: movability of skin; liberating incisions; formation of flaps with pedicles; implantation of entirely separated portions of skin.—Skin-grafting by the methods of Krause, Réverdin, and Thiersch.—Grafts of skin or mucous membrane taken from animals.—Hair-grafting.—Plastic operations for defects in other tissues (muscles, tendons, nerves, bones).

§ 41. **Plastic Operations for Cutaneous Defects.**—If the loss of substance in the tissues is so great that it cannot be remedied by simply suturing together the borders of the wound, we perform what has been called by the general name of a plastic operation, for remedying the defect or bringing about a more rapid cicatrisation.

We shall first take up the operative treatment of loss of substance in the skin. These defects are either fresh and the result of an injury or an operation, or they are old or congenital, or made up of a granulating wound surface. For treating such defects in the skin, or for hastening cicatrisation, there are in general two principal methods:

1. The closure of the defect by traction upon the skin in the neighbourhood, or by the formation of a cutaneous flap, which is freed from the underlying parts in such a way that it still possesses a bridge of skin at some portion of its circumference, called a pedicle, connecting it with the neighbouring skin.

2. The defect is also remedied by the transplantation or implantation of an entirely detached portion of skin. The first method, in which the defect is remedied by traction on the surrounding skin and by the formation of a movable flap with a pedicle, is what is ordinarily meant by a plastic operation.

Defects not only in the skin, but also in muscles, tendons, nerves, and bone, can be remedied by plastic operations—i. e., by the formation of flaps with pedicles or by the transplantation of portions of tissue entirely separated from their original surroundings. Modern aseptic surgery has made great advances in plastic operations and in the grafting of different tissues on others.

The cutaneous defects in which plastic operations are called for are caused by injuries and by diseases of every description (wounds from freezing or burning, inflammation causing necrosis, operations for tumours, malformations like harelip, ectopia vesicæ, etc.). Plastic operations are also indicated in cicatrices causing deformity or loss of function in a part. The ancient surgeons, particularly in India, were skilled in this branch, having plenty of opportunity for performing rhinoplasty and otoplasty, on account of the frequency of the form of punishment which consisted in cutting off the nose or ears.

If small portions of the body, like the tips of the fingers or the nose, are completely cut off, they will sometimes reunite in their proper position by primary union if they are carefully sutured in place with every antiseptic precaution, provided the piece of tissue is not too large and not too much crushed, and the sutures are applied immediately after the receipt of the injury. We shall return to the subject of the reuniting of small, completely severed portions of tissue in the chapters on Injuries and the Repair of Wounds.

General Principles of Plastic Surgery.—The following is a brief statement of the general principles governing plastic surgery, the details of which for special plastic operations—such as rhinoplasty, cheiloplasty, the operations for ectopia vesicæ, etc.—will be considered in the text-book on Regional Surgery.

It is of the greatest importance for the success of any plastic operation, or for the union of a skin flap in its new bed, that the operation should be conducted with the strictest attention to asepsis. The borders of the wound should be as smooth and sharply outlined as possible, the flaps should be cut of adequate size, not too small or too thin, and the subcutaneous fatty tissue should be preserved in its connection with the flap. The sutures should be of catgut or fine aseptic silk, and should be so applied that the borders of the wound are held in exact apposition.

Coaptation of the Borders of the Wound and Freeing of the Skin from Underlying Parts.—The simplest way of closing a defect in the skin consists in drawing together the borders of the wound and uniting them with sutures. To render the edges of skin more movable, they can be dissected free, together with the attached subcutaneous fat, from the underlying parts. Thus cutaneous defects of the most diverse shapes, if not too large, may be easily closed, as illustrated in Fig. 131. Julius Wolff has recently elaborated this method of closing defects by drawing over them the adjoining skin, which has first been freed from the subjacent parts, and then suturing the edges of the skin. He has in this way closed large areas where loss of substance has occurred in

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skin and in bone, and has also applied it to widely opened joints. The skin is loosened for some distance around the wound, partly with

FIG. 131.—Union of the borders of an area where there has been a loss of substance in the skin; the edges of the skin are freed from the underlying parts and united by sutures: *a*, before inserting the sutures; *b*, after inserting the sutures.

the hand and partly with a blunt-pointed knife or scissors, and then brought over the wound and sutured (Berlin. klin. Wochenschr., 1890, No. 6).

In other cases it is best to make use of lateral liberating incisions; i. e., before or after inserting the sutures in the approximated margins of the wound, an incision is made parallel to and at one side of the suture line, in order to lessen the tension on the suture line (Fig. 132, *a*). As illustrated in Fig. 132, *b*, the liberating incisions cause slightly gaping wounds after the defect has been closed, but these usually heal rapidly by aseptic granulation.

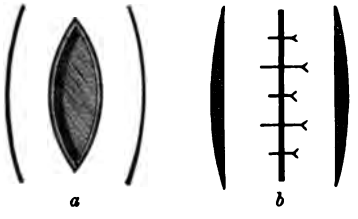


FIG. 132.—Lateral liberating incisions: *a*, before inserting the sutures; *b*, after inserting the sutures.

In a third category of cases the skin is drawn over a defect after making one or more incisions prolonged from the limit of the original defect in any required direction, and by this means forming a kind of flap. This is only a modification of the method of closing a defect by sliding the skin over it, and does not belong to the important method of plastic surgery about to be de-

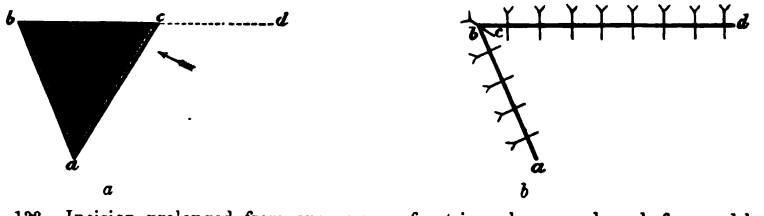


FIG. 133.—Incision prolonged from one corner of a triangular wound: *a*, before, and *b*, after, inserting the sutures.

scribed—namely, the formation of a flap with a pedicle. In Figs. 133, 134, and 135 are seen examples of the application of this method. In Fig. 133 the original incision has been prolonged in the line *c d*, and

the portion of skin *a c d* is thus rendered capable of being moved, *c* being drawn over to *b*, and the two borders of the defect are united with sutures, giving the result illustrated in Fig. 133, *b*. In the same manner, under other circumstances, a second incision can be prolonged from the original defect at *b*. When the three-cornered defect is closed by sutures there results some slight puckering of the skin at the sides. Burow remedies this by excising small three-cornered portions of skin

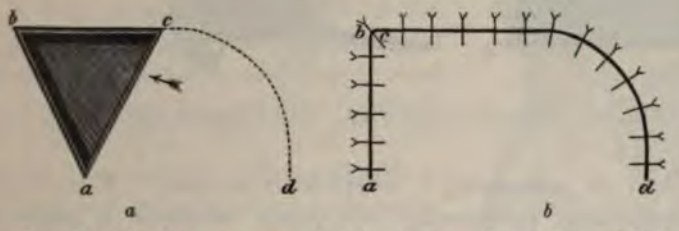


FIG. 134.—Curved incision from one corner of a triangular wound: *a*, before, and *b*, after, inserting the sutures.

in this region. This plan of excising a triangular-shaped portion of tissue, which Burow introduced, is at present but little used. In Fig. 134 the liberating incision *c d* is prolonged from the edge of the defect in a curved direction, and here also a second curved incision from *b* can be employed with advantage for closing the defect by sliding over it a portion of the adjoining skin. In Fig. 135 four lateral incisions

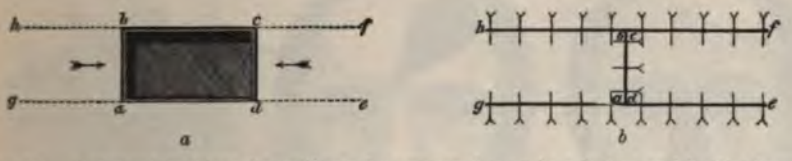


FIG. 135.—Prolonged incisions for uniting a four-cornered wound: *a*, before, and *b*, after, inserting the sutures.

are made for closing a quadrilateral defect. This principle of making lateral incisions or prolonging the original incisions, followed by drawing the skin over the defect, is capable of almost endless variations.

Formation of Flaps with Pedicles.—The most important method used in plastic surgery consists in fashioning flaps which have a pedicle—i. e., cutaneous flaps which remain connected with their original locality in the skin by means of a bridge or pedicle through which they are nourished, but throughout all the rest of their extent they are completely separated from their original bed. After this has been done the flap is laid in the defect, as illustrated in Fig. 136, *b*. In Fig. 136

two lateral flaps are fashioned (Fig. 136, *a*) and placed in the defec (Fig. 136, *b*), so that Fig. 136, *c*, results when the edges of the woun are united by sutures. In Fig. 137, *a b*, and Fig. 138 are illustrate

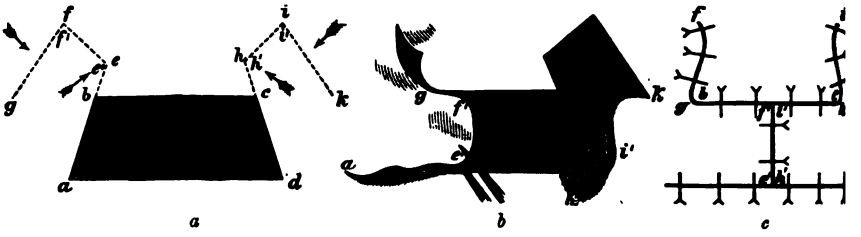


FIG. 136.—Formation of two lateral flaps of skin: *a* and *b*, before, *c*, after, inserting the sutures.

the method of performing a complete rhinoplasty. For details and other methods of performing rhinoplasty reference is made to the Regional Surgery.

When flaps with pedicles are used care must be taken that the blood supply is good and that primary union is obtained. The pedicle must be so situated that as many vessels as possible enter the flap; and the pedicle must not be too narrow or too thin. The flap, particularly the portion constituting the pedicle, is freed with every precaution for preventing its becoming too thin. Moreover, it is important that the

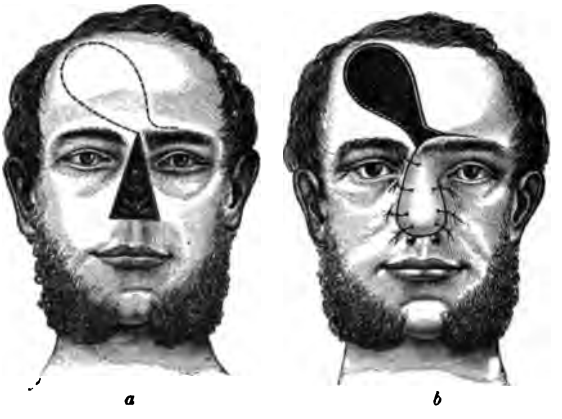


FIG. 137.—Rhinoplasty: *a*, freshening of the borders of the defect in the skin, and formation of the pear-shaped flap on the forehead; *b*, after placing the flap over the defect in the skin.

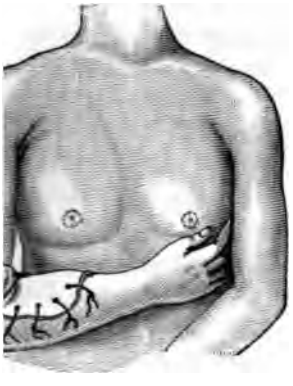
FIG. 138. — Langenbeck method for performin rhinoplasty.

part representing the pedicle should not be subject to too much tensio when the flap is implanted on the defect, for otherwise the nutritio might be materially impaired.

Plastic surgery performed with flaps having a pedicle was the form hich it was especially used by Indian surgeons, and they probably nated it.

laps have also been fashioned from portions of the body widely ıted from the defect, as we shall see when we take up rhino-. Tagliacozzi (Taliacotius, 1597), a ·ian of Bologna living in the sixteenth ·y, was the first to use a flap fashioned the skin in the biceps region of the ınd after placing the arm over the defect and allowing the flap to heal ıe latter, he cut the flap loose by divid- s pedicle (Fig. 139). This Italian d, as it is called, is only applicable to exceptional cases in which good mate- r making the flap cannot be obtained neighbourhood of the defect. The ı method is usually performed in three : (1) The formation of a flap which ıs attached by two pedicles; the flap ırated from the underlying parts after making two lateral inci- and its reunion prevented by iodoform gauze or oiled silk placed the flap. (2) After granulation has become well established one

Fig. 139.—Italian method of performing rhinoplasty (Tagliacozzi and Graefe).



40.—Covering over of a cutaneous ect at the elbow by a pedunculated from the chest.

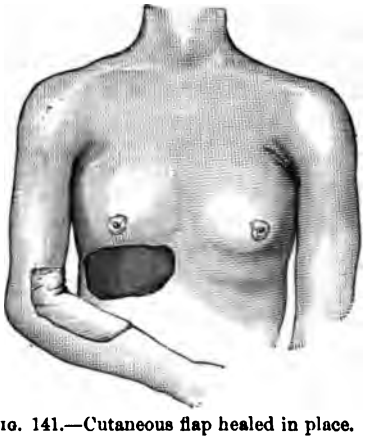


Fig. 141.—Cutaneous flap healed in place.

is divided, and the flap is sutured into the defect (Fig. 139). ter the flap has healed into its new bed, or after eight, ten, or n days, the other bridge of skin or pedicle is divided. Graefe

has performed the Italian method in one sitting by bringing the flap directly in contact with the defect (the German method). But the nutrition of the fresh flap is often poor, and it is likewise very apt to shrink.

The transplantation of pedunculated flaps from other parts of the body has of late come more into use in cases where skin-grafting is not possible. By this method a conservative treatment of severe injuries on the extremities can be carried out in many cases where it used to be impossible. Pedunculated flaps from the chest, for example, have been transplanted upon fresh or granulating defects in the upper arm or forearm (see Figs. 140 and 141), and have thus prevented or overcome contractures of the elbow joint after burns, avulsion of the skin, etc.

Granulating Skin Flaps.—Not only fresh but also granulating skin flaps are used, as we have seen, especially for closing congenital defects in the bladder (ectopia vesicæ). (See Regional Surgery.) For closing a defect in the wall of a cavity, as in ectopia vesicæ, and defects in the cavity of the mouth following, for example, the removal of a cancer, Plessing has recommended the use of flaps covered with epidermis. After fashioning a skin flap with a pedicle, its wound surface is provided with epidermis by skin-grafting (see page 147), and then the flap is allowed to heal into the defect.

Skin Flaps with a Pedicle of Subcutaneous Tissue—Gersuny's Method.—Gersuny was the first to show that a skin flap which possessed only a pedicle of subcutaneous tissue would receive sufficient nourishment to enable it to be used for plastic purposes, particularly in remedying defects of mucous membrane. The flap is simply turned into the defect like a door on its hinges, or it is drawn into a more deeply lying region through a suitably placed slit or wide button-hole.

§ 42. **Skin-grafting.**—The transplantation of skin for hastening the skinning over of granulating surfaces was first employed by the Indian surgeons, and was brought into use again by Réverdin in 1870. A granulating wound in which the corium is entirely absent can only become covered with skin by gradual ingrowth of the latter from the edges. It is only possible for skin to start to grow outward from the middle of a granulating surface when there still remains in this area remnants of the rete Malpighii or of the sebaceous glands. By skin-transplantation not only is the length of time required for a wound to skin over shortened, but the subsequent cicatricial contraction is considerably diminished. Pieces of skin containing the whole thickness of the cutis will very seldom heal in place, and consequently they should consist only of epidermis and a part of the cutis. Krause's method is

a good one. A strip of skin (as much as twenty to twenty-five centimetres in length and six to eight centimetres in width) is taken from the thigh, for example, and the defect thus made closed by a continuous suture. The subcutaneous fat is then removed from the strip of skin, and the latter cut into two, three, or more pieces. These pieces of skin are then placed on the wound surface and made to adhere by slight pressure. The factor of chief importance in this method of skin-transplantation is the strictest asepsis, a dry method of operating, and careful preparation of the wound surface to be covered. Neither the transplanted skin nor the wound surface should be treated with antiseptics, lest the integrity of the cells be damaged.

Thiersch's Method of Skin-grafting.—Thiersch's method is the one most frequently employed. In the case of fresh defects the skin is applied after the bleeding has been completely arrested, but in granulating wounds the layer of granulation is first removed with a knife or sharp spoon. It is possible, however, to graft skin on to a granulating surface, especially granulating bone. Moreover, skin can be grafted from a fresh cadaver before the onset of rigor mortis, or from a limb which has just been amputated. Epidermis cells remain alive for a surprisingly long time outside the body if they are kept moist in sterile salt solution or in sterile ascitic fluid. Ljungren kept pieces of skin from two days to more than three months in sterile ascitic fluid, and used them successfully for grafting. The microscopic examination showed that the epithelium had really multiplied by karyokinesis. Wentscher and Enderlen made similar observations. Wentscher kept some pieces of skin in sterile salt solution, and others dry in a closed bottle. In his experiments the freshest skin that was grafted successfully was seven days old, and the oldest twenty-two days.

Thiersch's method of skin-grafting is as follows: The instruments to be used are sterilised by boiling them for about five minutes in a one-per-cent. soda solution and are then placed in a sterilised six-tenths-per-cent. solution of common salt. Antiseptic solutions like bichloride of mercury and carbolic acid should not be used, as they endanger the vitality of the cells in the pieces of skin to be transplanted. The latter are taken preferably from the arm or the lower extremity, etc. The area of skin in question is thoroughly washed with sterilised soap and warm water and shaved. As large a razor as possible, or a microtome, is covered with sterilised oil, and while the skin to be cut is put on the stretch, *as thin flaps as possible* are shaved off from it. To secure rapid healing, the pieces of skin should be laid upon a wound from which the blood has been removed as completely as possible

(Garré). I mentioned above that it is not necessary, as Thiersch first taught, to remove the granulations, because it is perfectly possible to graft upon a granulating surface that has been thoroughly cleansed. The very thinnest graft contains, besides the entire thickness of the papillary layer, a part of the underlying stroma. In this way pieces of skin ten to twelve centimetres long and two centimetres broad can be made to heal into their new position. The larger grafts are carried upon an especially broad spatula and then spread out over the wound with a probe. Great care should be taken that the edges of the piece of skin do not roll up, and the separate pieces should be placed next one another with their edges just touching. This method is particularly valuable for fresh cutaneous defects caused by operations or injuries, for burns in the stage of granulation, for ulcers of the leg, for broad and deep granulating areas following operations for necrosis, etc. After removing a large, soft fibroma, I successfully covered with epidermis almost the entire hairy portion of the scalp in one sitting by Thiersch's method of skin-grafting; I also made a large permanent opening into the left pleural cavity for empyema and tuberculosis, and changed it into a gutter by use of the same method (see Regional Surgery, § 126). In short, the method is an excellent one. Thiersch has also transplanted the skin of a negro upon a white man and the skin of a white man upon a negro. The negro's skin took root on the white man with exceptional rapidity, but the attempt failed in the majority of cases in which skin was transplanted from the white man on to the negro, no matter whether a granulating or a fresh wound surface was used. It is interesting to note that the portions of white skin implanted on the negro gradually turned black, and *vice versa*. The histological investigations of Karg showed that the pigment does not originate in the cells of the rete Malpighii, but is brought to them by the wandering cells which come from the deeper-lying portions of tissue laden with pigment and find lodgment among the cells of the rete. Consequently the white skin implanted on the negro becomes gradually black, and the negro's skin implanted on the white man becomes white from ceasing to receive deposits of pigment. The pigment particles are probably identical with the cell granules discovered by Altmann and by him called bioblasts, and are probably formed from them by the help of the blood in some unknown way. According to Jarisch, the pigment of the negro's skin lies almost entirely in the deeper cells of the rete Malpighii and is entirely, or almost entirely, absent from the more superficial cells.

Dressings after Skin-grafting.—The *dressing* for a skin-grafted area should be one which does not adhere to its surface, as the pieces of

skin are easily torn off when the dressing is changed. In place of the wet dressings of oil or salt solution, which were at one time in general use, I employ dry dressings—i. e., I sprinkle the grafts with iodoform or dermatol powder, and apply rubber tissue with holes made in it, or iodoform gauze, which does not adhere so easily as sterile gauze, and later I use dressings of boric ointment. On the extremity careful immobilisation is necessary. The first dressing is kept on for from three to five or eight days. Great care is necessary, in removing the dressing, not to disturb the grafts. If the grafts have "taken," the area they cover presents a mosaic appearance due to the separate pieces of skin used for the grafts. Later on the borders of the separate pieces of skin become less and less marked, and occasionally become quite indistinguishable. The epidermis generally comes off, and is liable to give the erroneous impression that the grafting has failed. Success is easily prevented by suppuration or bleeding. E. Fischer has made the interesting observation that those skin-grafts become attached the easiest which are taken from and transplanted upon parts which have previously been rendered anæmic by the use of Esmarch's rubber bandage.

The Histological Changes in Skin-grafting are in general the same as in primary union of a wound. The transplanted piece of skin is at first passive, but from the third day on it becomes supplied with blood by vascular sprouts from the wound. In spite of this interruption for two days in the circulation, most of the tissue elements of the graft remain alive; only the horny layer, a portion of the rete Malpighii, and most of the vessels die. From the third to the fourth day on the graft takes an active part in healing in place; the epithelial cells, including those belonging to the divided hair follicles and gland ducts, send out proliferations of cells into the underlying exudate. In about fourteen days the granulation tissue is replaced by connective tissue. The subepithelial layer arising from the granulation tissue formed from the wound surface is the real cicatrix. Complete union of the transplanted skin on to its new bed requires, however, several weeks and sometimes months, and we must wait this length of time before subjecting the new skin to external injurious influences, otherwise it may break through. According to Enderlen the Thiersch grafts do not show a liberal supply of elastic fibres until one and a quarter to one and a half years afterward. The greater part of Krause's graft (see page 146) dies, and is gradually replaced by newly formed tissue, which corresponds in shape to the transplanted skin, and even contains newly formed papillæ. A cicatrix of this sort, on account of its firmness and slight tendency to contraction, is much better than the usual scar.

Wölfler's Transplantation of Mucous Membrane.—Wölfler (see Langenbeck's Archiv, Bd. xxxvii) has successfully transplanted mucous membranes taken from man and animals upon defects in various mucous membranes. This method is to be greeted as a new and valuable advance in the treatment

of defects in mucous membrane, such as strictures and defects in the urethra, conjunctiva, cheek, etc. Gersuny, Witzel, and others have remedied defects in mucous membranes by turning in flaps of skin possessing a pedicle of subcutaneous tissue only (see page 146).

Implantation of Hair.—Schwenninger and Nussbaum have attempted to implant hair by strewing it over a granulating area where there has been a loss of skin. If the root sheath still remained attached to the hair, it became adherent and formed a centre from which cicatrisation proceeded, but the hair itself fell out after a few days. Hairs without their root sheath did not become attached at all.

Mangoldt's Method of Skin-grafting.—Mangoldt recommends scraping the sterilised skin with a razor, down to the papillary layer, and spreading the mixture of epithelial cells and blood thus obtained upon a clean bloodless non-granulating wound. I have tried this method and can recommend it.

Transplantation of Skin and Mucous Membrane from Animals (*Rabbits, Frogs*).—The skin and mucous membranes of animals have also been successfully transplanted upon man. The conjunctiva of a rabbit has been successfully grafted in a defect of the human eyelid. Baratoux and Dubousquet-Laborderie have succeeded in implanting the skin of frogs upon granulating wounds in man. The pigment disappeared after ten days, and the graft took on more and more the appearance of human skin.

§ 43. **Plastic Operations on other Tissues** (*Tendons, Nerves, Muscles, Bones*).—Plastic operations and graftings are performed not only upon the external cutaneous surface of the body, but also upon other tissues, such as tendons, muscles, nerves, and bones. We shall refer to this in detail later on. At present the following brief account will suffice: Defects or loss of substance in a tendon can be remedied by cutting flaps with pedicles from one or both divided ends of the tendon and bending them back and uniting them by means of sutures of catgut.

Loss of substance in a tendon may also be remedied by filling the intervening space with threads of catgut or silk, which act as a framework for the tendon tissue that is to be newly formed. The same method can be used in the case of nerves. Attempts have been made to remedy defects in nerves, muscles, and tendons by means of corresponding tissues taken from animals—a rabbit, for instance. But these transplanted portions of nerves, tendons, and muscles never heal in place permanently as such. The transplanted portion of a nerve acts merely as a guide for the newly formed nerve fibres growing from the proximal toward the distal end of the injured nerve. A transplanted portion of muscle is always cast off or is absorbed (Volkmann).

Defects in bone have been remedied by living and dead bone. The best method of osteoplasty consists in the use of a pedunculated flap

containing skin, periosteum, and bone, or merely periosteum and bone. Defects may also be filled in with completely separated pieces of living bone, or with different kinds of non-living material. Thus, use has been made of pieces of bone taken from young animals or children, also of decalcified bone, sterile bone, charcoal, ivory, and of celluloid plates for defects in the skull. For filling up cavities in bone, hardening materials have been used, such as plaster of Paris, copper amalgam, and Richter's cement.

SECOND SECTION.

THE METHODS OF APPLYING SURGICAL DRESSINGS.

CHAPTER I.

THE ANTISEPTIC AND ASEPTIC PROTECTIVE DRESSINGS FOR WOUNDS.

General principles governing the antiseptic and aseptic dressing of wounds.—History.—The typical Lister dressing; its simplification.—Antisepsis and asepsis.—The most commonly used antiseptic or aseptic dressing materials (gauze, cotton, jute, lint, wood fibre, moss, etc.).—The different antiseptics; their uses and dangers (poisoning from carbolic acid, bichloride of mercury, iodoform, etc.).—Which antiseptics are of value?—Which antiseptic and aseptic methods of dressing are the best?—Antiseptic and aseptic change of dressings.

§ 44. **General Principles governing Antiseptic or Aseptic Dressings.**—After learning, in the previous section, the main principles governing the modern aseptic method of performing operations, we come to the question of what dressings should be used for covering the wound, and the discussion of the methods of applying surgical dressings. It is a part of surgical technique which requires indefatigable diligence and care. A correct application of the dressings, and a carefully conducted after-treatment of those who have been operated upon or wounded, are matters of the greatest importance.

As we are aware that all infection of the wound is caused by micro-organisms, by the omnipresent bacteria, it follows that we should conduct the after-treatment of the wound in such a way as to preserve it from the damaging effects produced by micro-organisms, and with the same care that is used in performing an aseptic operation.

The surest and simplest way of preventing subsequent infection in a clean, aseptic wound—such as one resulting from an operation—is to cover it with a germ-free dressing which has been sterilised by hot steam (see pages 15, 16). In private practice, dressings are still much used which have been impregnated with antiseptics like carbolic acid and bichloride of mercury. That method of treating a wound is the best which offers the greatest security against subsequent infection and

most readily carries off and absorbs the discharge from the wound. We operate, without exception, according to the rules of asepsis, and consequently the same preventive measures should be carried out in the after-treatment of the wound until it has become entirely healed. Infected wounds are to be cleaned as perfectly as possible from any dirt or foreign bodies which may be present, and are best disinfected by a 1 to 1,000 solution of bichloride of mercury.

Historical Remarks on the Listerian Method of treating Wounds.—The antiseptic as well as the aseptic occlusive dressing for wounds has advanced very gradually to its present state of perfection. Lister began the use of his antiseptic occlusive dressing at the Glasgow hospital in 1865, and published his first communication on the subject in 1867. Thiersch was the first German surgeon to bring into notice Lister's antiseptic method of treating wounds, describing it in his work on the repair of wounds.* Then followed the contributions of Schultz and Von Lesser, who had in Edinburgh itself made themselves familiar with Lister's methods and praised them very highly. Even before Lister's discovery, antiseptics, especially carbolic acid, had been used for dressings, but to Lister belongs the immortal honour of having conceived and intelligently carried out the aseptic method of operating and of applying dressings by the use of which it is possible to keep fresh wounds from infection. In 1872–'73 the first trials were made in Germany with the Lister dressing. In the German Surgical Congress of 1874 Volkmann reported his experiences with the Lister dressing, and in 1875 he published his "Beiträge zur Chirurgie," in which were described the remarkable and hitherto unheard-of successes obtained by the use of Lister's method of operating and applying dressings. In 1874–'75 the Listerian method came into general use in Germany, and then started on its triumphant progress over the entire civilised world. Never was surgery so radically changed for the better as after the introduction of Lister's method for the treatment of wounds. In the very hospitals where the infectious wound diseases had raged the worst during the preantiseptic period, the severest operation wounds and injuries now healed up without suppuration and without secondary disease. After such remarkable success, the opponents of the method who arose here and there were forced to give up the contest.

The Original Typical Lister Dressing.—The typical Lister dressing used at first was applied in the following manner: The disinfectant was carbolic acid, used in a two-and-a-half- to three-per-cent. solution for non-infected, and in a four- to five-per-cent. solution for infected wounds. Lister covered the wound, or, rather, the suture line, with carbolic acid and paraffine spread on oiled silk, the whole being called a "protective" for keeping the irritating substances in the dressings away from the wound. The protective was made of green silk cloth, painted over with shellac, and covered on one side with a mixture of one part dextrin, two parts pulverised starch, and fifteen parts of a five-per-cent. carbolic-acid solution. Before using, the protective was disinfected by a three-per-cent. carbolic solution. The green colour of the protective was changed to black by decomposition of the wound-secretion, which

* Pitha-Billroth's Handbuch der Chir., Bd. i, p. 559.

was a matter of practical importance for determining whether the wound was perfectly aseptic or not. Besides the silk protective, a cotton protective was also in use. Over the protectives Lister placed eight or more layers of dry gauze impregnated with carbolic acid, and between the two outermost layers he inserted a water-tight material made of cotton and gutta-percha (mackintosh). The layers of carbolised gauze extended some distance beyond the limits of the wound, particularly when considerable discharge was expected. Lister used carbolised gauze bandages instead of the ordinary strong muslin bandages. He impregnated them with carbolic acid in the same way as the gauze compresses used in the dressing. The typical Lister dressing was always put on and changed in the early days under the carbolic spray (see page 14).

Improvements in the Original Lister Dressing.—Very soon after its introduction, Lister's carbolised gauze dressing was materially simplified and improved, particularly by German surgeons. The carbolic spray used during the change of the dressings was done away with, also the protective and the mackintosh. The wound is now covered only with aseptic dressings, and stress is laid upon the importance of having the secretion from the wound dry quickly in the dressing. In place of the dressings impregnated with antiseptics, we now use those which have been sterilised by steam at a temperature of 100°–130° C. The use of antiseptics has been curtailed more and more. The instruments are sterilised by boiling them for five minutes in a one-per-cent. soda solution, and bichloride of mercury 1 to 1,000–5,000 is used as the antiseptic for the wound. Sterilised water, or a sterilised six-tenths-per-cent. solution of common salt, is used a great deal during operations, particularly in the peritoneal cavity, etc. (see § 6).

§ 45. **The Most Common Antiseptic and Aseptic Dressings for Wounds.**—The modern surgeon uses particularly:

1. *Antiseptic solutions* for cleansing the wound and for disinfecting the materials used in the dressings. The most suitable are three- to five-per-cent. solutions of carbolic acid, and aqueous solutions of bichloride of mercury (1 to 1,000–5,000). He also uses antiseptic powders, such as iodoform, dermatol, bismuth, and naphthalene, for dusting over wounds, especially if they have the form of a cavity or are not closed by sutures, or are already suppurating or granulating. Instead of antiseptic solutions, sterile salt solution and sterile water are used upon the wound.

2. *Absorbent materials*, such as unstarched gauze, mull, jute, prepared moss, wood wool, my own specially prepared wool, and cotton from which all fatty matter has been extracted. These are sterilised by subjecting them to steam heat at a temperature of 100°–130° C. in a sterilising apparatus.

The dressing materials impregnated with antiseptics, like carbolised and bichloride gauze, were formerly in very general use; but it is simpler and better to sterilise them all by heating them as just described,

at a temperature of 100°–130° C. in a sterilising apparatus. Moreover, it has been proved that dressing materials impregnated with antiseptics and kept in a dry condition do not remain sterile, but after a time all sorts of bacteria have been cultivated from them (Schlange, Ehlers, and others).

The modern surgeon no longer uses for dressing wounds the material called charpie, which was formerly much in vogue, and consisted of bundles of thread made by pulling to pieces bits of linen cloth. This charpie has caused much harm; it was full of dirt and wound poisons, and consequently has killed many a patient by exciting suppuration and infectious wound diseases (erysipelas, pyæmia, septicæmia).

The dressing materials are fastened in place by mull bandages which have been soaked in a three-per-cent. carbolic or 1 to 1,000 bichloride solution, and gauze bandages are applied over these. The bandages subsequently dry and cause the whole dressing to form a firm, well-fitting support. When it is necessary to immobilise an extremity, the dressing may be strengthened by adding splints of wood, metal, wire, or thin pliable wooden hoops.

Of the numerous materials used for making aseptic and antiseptic dressings, the following are in most common use:

Mull or Gauze.—The most extensively employed material is soft, unfinished gauze or mull. Mull is a most excellent substance for dressings, being soft and a good absorbent, but is somewhat expensive. It is impregnated with every kind of antiseptic, particularly bichloride of mercury, carbolic acid, and iodoform, but it is best sterilised by subjecting it to steam heat at 100° C. (212° F.), as we have described. For the method of preparing this or that particular kind of antiseptic gauze—e. g., carbolised, or bichloride, or iodoform gauze, etc.—reference is made to the description of the various antiseptics which is given farther on.

Other and cheaper materials are recommended as substitutes for the more expensive mull; these are jute, moss, prepared moss, wood wool, etc.

Cotton.—Cotton is not suitable for placing directly upon the wound, as it does not sufficiently absorb the secretion from the wound, and allows it to collect underneath and decompose. But after covering the wound with a thick layer of some absorbent material, like mull or the author's prepared wool, it is then a good plan to use dry cotton, which has been freed from fat, as the outermost covering of the dressing.

Lint.—Lint has been manufactured, especially in England, since about the beginning of the present century. In combination with antiseptic substances, especially boric acid (making boric lint), it is very much used as an antiseptic material for dressings.

Jute.—Jute, also called Indian hemp, consists of the woody fibres of the different kinds of corchorus, particularly the *Corchorus capsularis*, a plant growing in the East Indies and China. It is an excellent substitute for cot-

ton. It is best used in the shape of jute pads—that is, jute sewed up in bags of sterilised gauze.

Flax.—Flax is recommended by Medwedew, Makuschina, and others. It is usually made up into small bundles, which are boiled in lye for three hours and then left to stand in the same liquid for eight to ten hours longer. After washing it five to seven times in clean water, the flax is dried and combed, and finally becomes a completely white, soft, and delicate material which is very absorbent, and, like jute, is used in the form of small pads. Flax is about five or six times cheaper than cotton.

Peat.—Neuber recommends peat, having, by chance, observed a compound fracture of the forearm which healed perfectly under softened peat which had been applied to it. Peat dressings have now gone entirely out of use.

Peat Cotton.—Redon has made from peat a material like cotton, or rather tow, which Lucas-Championière considers suitable as a dressing for wounds, on account of its softness, its great power of absorption, and its cheapness.

Moss.—Leisrink recommends ordinary moss as a most excellent material for dressings, combining in itself all the advantages which a dressing should possess. It is soft, has great power of absorption, and is cheap. The dry moss should be sterilised by heating it to a temperature of 100° to 130° C., and then placed in the dry state in sterilised gauze bags. The wound is covered with dry sterile gauze. Hagedorn has also recommended moss as a good material for dressings. The moss should be collected from the woods, picked apart, dried, and then heated in an oven for several hours at a temperature of 100° to 130° C.

Moss Felt.—Leisrink has recommended tablets of moss felt in the place of moss cushions. The preparation of the felt is as follows: The freshly gathered moss is pulled apart, washed, and then steeped in water, after which it is made into felt and put in a press. According to the greater or less amount of moss used, thick or thin tablets are made which consist of hard or soft felt, depending upon the pressure exerted upon the pulp. The dried felt can be sewed up in gauze bags of different sizes and shapes. Hagedorn's moss pulp and moss-gauze pulp, soaked immediately before use in sterilised salt solution, water, or bichloride, are excellent materials.

Wood Wool.—P. Bruns and Walcher use for dressings wood wool or wood which has been rubbed into small particles by a grindstone. This material has great powers of absorption, is light, soft, and cheap. Wood wool is packed into gauze bags, and used for dressings in the shape of wood-wool cushions. This dressing is simplified by combining with the wood fibre a twenty-per-cent. admixture of ordinary cotton wool, thus rendering the preparation of wood-wool cushions superfluous. The wood-wool dressings are remarkable for their great absorptive powers, and they can be left in place upon large wounds for two to three weeks, and the secretions from the wound will become dry during this time. The wound is covered with a layer of gauze in order to prevent the dressing from adhering.

Wood Fibre.—Kümmel has recommended wood fibre for an antiseptic dressing material. It is made from pine or fir needles, and forms a dry, green substance made up of fine fibres. It is sewed up into gauze bags.

Wood Wadding.—Rönnberg recommends wood wadding, which is a substance made during the process of manufacturing paper. It is pure cellulose, or a brown, woody material in a finely divided state.

Marly Scraps.—Tolmatschew has recommended marly scraps as an extremely cheap material for dressings. It is a product in the manufacture of marly or Scotch gauze, and consists of thready scraps made in tearing off tangled threads. Wolynzer recommends asbestos.

Paper Wool.—I can recommend paper wool as an excellent absorbent material, and one which forms a soft dressing, very comfortable for the patient. It is made in the manufacture of paper from cloth and is cheaper than mull.

Maas claims that the absorbent powers of dressings can be increased very perceptibly by the addition to them of such hygroscopic substances as glycerine or common salt, and thus those dressings which have but little power of absorption, such as cotton, tow, jute, etc., can be materially improved—a consideration which would be of much value, particularly during war times.

Glass Wool.—Glass wool, a substance having very delicate fibres and easily sterilised, was at one time used in place of Lister's protective for covering the wound.

§ 46. **The Different Antiseptics.**—Of the various antiseptics which are employed in the treatment of wounds and for dressing purposes, carbolic acid and bichloride of mercury are the most widely used. Carbolic acid is the antiseptic which is most intimately connected with the reform in modern surgery, and was chosen by Joseph Lister from among all the antiseptic drugs known at that time as the best adapted for carrying out his new methods. Since the introduction of asepsis the employment of antiseptics has diminished a great deal.

Carbolic Acid.—*Carbolic acid* or *phenol* (C_6H_6O) was isolated by Runge, in 1834, from coal tar. It forms colourless crystals, and is volatile, very caustic, and soluble at ordinary temperature in 15 parts water. It is very poisonous to animals and plants. It is ordinarily used in the form of a two-and-a-half- to three-per-cent. aqueous solution for cleansing a wound, disinfecting instruments, for washing out pads or sponges during an operation, for a spray, or for the hands. The stronger five-per-cent. solution is used for wounds already infected, but always with caution on account of the danger of poisoning. The five-per-cent. solution should invariably be subsequently washed away by a three-per-cent. solution. Moreover, the three- to five-per-cent. solutions are serviceable for disinfecting the field of operation, for storing sponges, silk, catgut, etc. Five- to ten-per-cent. carbolised glycerine is used in the same way. Laplace has increased the solubility and the disinfecting power of carbolic acid by the addition of crude sulphuric acid; he forms a mixture consisting of twenty-five-per-cent. crude carbolic acid with an equal amount of crude sulphuric

acid of a similar strength, and, after heating it, allows the mixture to cool off. The same result is obtained by the addition of a two-per-cent. solution of hydrochloric acid. At present we avoid washing out a wound with a three- to five-per-cent. solution of carbolic—a practice which was formerly much in vogue—as we now know that it is unnecessary and even dangerous in the case of large wounds. It should always be borne in mind that carbolic acid is a powerful irritant to the tissues, and is, furthermore, poisonous. Children and anæmic and cachectic individuals are particularly prone to carbolic-acid poisoning. A warning should be given here against the prolonged use of wet dressings of one- to five-per-cent. carbolic. Gangrene may easily result from their use, particularly on the fingers and toes.

Carbolised Glycerine.—Carbolised glycerine is an excellent disinfectant for instruments and the hands of the operator. It consists of glycerine containing ten to twenty per cent. of carbolic acid. We smear the finger with five-per-cent. carbolised glycerine or carbolised vaseline for making rectal or vaginal examinations.

Carbolised Gauze.—Carbolised gauze, which was at one time used a good deal, is prepared as follows: 500 grammes of gauze is impregnated with a mixture containing 1,000 parts alcohol, 200 parts colophonium, 20 parts castor oil, and 50 parts carbolic acid.

Carbolic-Acid Poisoning.—Carbolic acid is, as has been said, poisonous, and, even when used externally, can produce dangerous symptoms which may terminate in death. I once saw a very rapidly fatal case of poisoning in a student. A friend gave him a teaspoonful of five-per-cent. carbolic acid by mistake, and unfortunately the stomach pump was not used by the physician called in. In another similar case the patient was saved by immediately washing out the stomach.

The symptoms of carbolic-acid poisoning are headache, dizziness, nausea, and vomiting. The change in the colour of the urine to olive green or black is an important symptom in making the diagnosis. But the intensity of the poisoning bears no constant relationship to the intensity of the discoloration of the urine. With even strikingly dark urine the patient may feel very well. The carbolic acid is found in the urine in the form of phenol-sulphuric acid. In the most severe cases there ensue bloody diarrhœa, hæmoglobinuria, and symptoms of collapse, and convulsions caused by the increased reflex excitability of the spinal cord (Salkowsky, Gies); then follows a marked fall of temperature, the pupils react slowly or not at all, the respiration becomes superficial, consciousness is lost, and death takes place from paralysis of the vasomotor centre in the medulla. In the case of children and weakly individuals, the external application of carbolic acid should be used with great caution. Furthermore, many apparently strong individuals are very susceptible to this drug.

Clinically two distinct forms of phenol poisoning are recognised—acute carbolic-acid poisoning, and the chronic, which takes the form of a maras-

mus (Falkson, Czerny, Küster). The chronic poisoning is characterised by headache, hiccough, debility, and loss of appetite—symptoms which were of frequent occurrence among surgeons who operated very much under the carbolic spray. Falkson assisted at an operation for two and a half hours where a two-per-cent. carbolic spray was used, and in the following twenty-four hours he found 2.06 grammes of carbolic acid in his urine, an amount fourteen times greater than the maximum dose of 0.15 gramme allowed by the Pharmacopœia.

Detection of Carbolic Acid in the Urine.—Millon's reagent (a solution of mercury in ordinary fuming nitric acid) and bromine water give a very useful reaction with carbolic acid after the urine has been previously acidulated with hydrochloric or sulphuric acid and then distilled. Carbolic urine assumes a violet colour upon the addition of chloride of iron, and if warmed with Millon's reagent it takes on a purplish-red colour, or with hypochlorite of sodium a dark-brown colour; if treated with bromine water a precipitate of tribromphenol results. A very good reaction for phenol is produced by a hydrochloric-acid solution (hydrochloric acid fifty centimetres, distilled water fifty centimetres, and calcium chloride 0.20 gramme) and a pine stick (Hoppe-Seyler, Tommasi). Tommasi describes it as follows: Equal quantities of urine and ether are shaken together, the supernatant liquid is then decanted and the piece of stick is soaked in it until saturated, when it is plunged quickly into the hydrochloric-acid solution and finally exposed to the sunlight. The ensuing reaction consists in a blue coloration of the stick; but if carbolic acid was not present in the urine there will be no change in colour, or at the most a slight change to a faint green colour. This reaction will enable the slightest trace of carbolic acid to be recognised in urine or water. If the stick is exposed to the sunlight too long, the colour eventually disappears.

The Presence of Carbolic Acid in the Different Organs after Poisoning.—Hoppe-Seyler has measured the amounts of phenol contained in the separate organs after phenol poisoning, and he has found that the brain and kidneys hold more than the others, consequently investigation should be first directed to these organs in cases of suspected carbolic-acid poisoning.

Treatment of Carbolic-Acid Poisoning.—The treatment of poisoning from this drug consists in stopping its use immediately—for example, by removing the carbolic dressing. Sonnenburg has recommended the internal administration of Glauber's salts (sodium sulphate) to hasten its excretion through the kidneys in the form of the innocuous sulpho-carbolate of sodium. The sulphate of sodium should be given in large doses by the mouth or rectum, though its efficacy is somewhat doubtful. The rest of the treatment is symptomatic—i. e., the symptoms are treated as they arise, and stimulants and large amounts of water are given internally. If the poisoning is produced by swallowing carbolic acid, the stomach pump should be used immediately.

Bichloride of Mercury (corrosive sublimate, $HgCl_2$, hydrargyrum bichloratum corrosivum) is one of the oldest drugs, and, according to Pearson, was known to the Chinese, who have made it from cinnabar from time immemorial. Billroth, Buchholtz, and Robert Koch were the first to determine and make known its great antiseptic value.

Koch showed that bichloride of mercury, even in the dilution of 1 to 330,000, completely arrested the growth of anthrax bacilli, and in a solution of a strength of 1 to 1,000–5,000 almost instantly killed the anthrax spores. As the bichloride is the most poisonous of all the salts of mercury, it was natural that many surgeons at first would have nothing to do with it in the treatment of wounds. But now it is a great favourite among surgeons, and is almost always used for disinfecting the field of operation, the hands, and the wound, in aqueous solutions varying from 1 to 1,000–5,000. Besides the marked antiseptic power of bichloride it has the advantage of being much cheaper than carbolic acid. A one-fifth-per-cent. solution of bichloride can be used for the storage of silk (after boiling it half an hour in a one-fifth per cent. bichloride solution) and of catgut which has been sterilised by the method already described. Bichloride is unsuitable for the disinfection of instruments, as we have seen, and for these a three-per-cent. solution of carbolic acid, or half to one per cent. creosol are employed.

Stability of Bichloride Solutions.—If ordinary water, which has not been distilled, is used for making bichloride solutions, an insoluble compound of mercury will separate after a time, which, according to Fürbringer, is a trioxychloride, or a dioxychloride, or a tetraoxychloride, and is thrown down by the alkaline carbonates in the water. For preventing this precipitation of the bichloride which occurs in ordinary spring water, Fürbringer recommends the addition of acids (salicylic, hydrochloric, and acetic acids, 0.5 to 1 gramme per litre); Laplace recommends tartaric acid (one part bichloride, five parts tartaric acid); while Bergmann and Angerer recommend common salt (one gramme sodium chloride to one gramme bichloride of mercury). Krönig claims that the addition of acids and sodium chloride diminishes the antiseptic action of bichloride. A small amount of sodium chloride has the least effect in this particular. Krönig recommends that only enough sodium chloride should be added to the bichloride as will suffice to form the easily soluble sodium salt of mercurial chloride (Na_2HgCl_4)—i. e., ½ gramme of sodium chloride to 1 gramme bichloride of mercury. The bichloride tablets which are in such general use should contain this percentage. Schillinger, Fürbringer, and Meyer have demonstrated that the stability of a bichloride solution depends also upon whether the vessel in which it is contained is air-tight or not, and also upon the amount of exposure to light.

Preparation of Bichloride Gauze.—Bichloride gauze, which has been used much more in the past than it is now, is made by saturating gauze with a mixture of ten parts of bichloride of mercury, five hundred parts of glycerine

ten hundred parts of alcohol, and fifteen hundred parts of water. This makes a mixture which is sufficient to saturate about sixty to seventy metres of gauze, which should be dipped into it and then dried. Ordinarily gauze containing one third per cent. of bichloride answers sufficiently the purposes of an antiseptic dressing. Cotton, jute, etc., can also be impregnated with bichloride in the same way.

Bichloride Poisoning.—As we have previously remarked, *bichloride of mercury* is a *dangerous poison*, and must be used with very great caution, especially in the case of children and sickly individuals. The symptoms of poisoning manifested after the external exhibition of the drug consist in a feeling of dizziness, restlessness, general malaise, vomiting, salivation, ulcerative stomatitis of the gums, and toward the last there is a bloody diarrhœa and occasionally bleeding from the mouth and nose. The urine contains mercury and albumen. Locally, when the bichloride dressing has been applied, there is sometimes an eczema, with persistent itching and burning of the skin, particularly if the dressings have been put on too wet, and this should therefore be avoided. The lesions of bichloride poisoning are as follows: Hyperæmia of the kidneys, marked changes in the epithelial cells of the kidneys—particularly the convoluted tubules, but also the straight ones—and hyaline casts. There are also ulceration and hyperæmia of the small intestine, desquamation and ulceration of the large intestine, swelling and necrosis of the liver, calcareous infarcts and crystalline formations in the kidney and liver, subendothelial hæmorrhages in the heart, and marked swelling of the parenchyma of the spleen. In consequence of the serious changes in the kidneys, complete suppression of urine may result, which is then to be looked upon as the real cause of death. In chronic bichloride poisoning also the changes in the kidneys are particularly characteristic, and may be for a long time the only symptom (Sonnenburg).

It is necessary, moreover, to use bichloride of mercury carefully in the interests of the physician and of the assistants. Even then they will occasionally show signs of poisoning in the form of salivation and inflammation of the gums, or mercury and albumen will be present in the urine. Since asepsis has taken the place of antisepsis in operations, and we have limited the use of bichloride, the cases of poisoning from this drug, like those from carbolic acid, have become much less common. One should operate as "dry" as possible, and avoid irrigating and washing out the wound with bichloride solutions whenever this can be done, and use only dressings which have been sterilised by steam, etc. Operations in the thorax, peritoneal cavity, rectum, and vagina must be conducted with very great care as regards the use of bichloride, and the latter should not be employed for washing out the pleural cavity after an operation for empyema, nor for irrigating the uterus or rectum, etc.

Treatment of Bichloride Poisoning.—The treatment of poisoning by bichloride of mercury consists in immediately stopping its use; the rest is symptomatic—i. e., treatment of symptoms as they arise.

Salicylic Acid.—Salicylic acid ($C_7H_6O_3$) exists in the form of small needle-shaped crystals, which are odourless, and only slightly soluble in cold water (1 to 300–400), but readily soluble in hot water, alcohol, ether, or glycerine.

Salicylic acid is not volatile like carbolic acid, from which it is made synthetically by treating carbolate of sodium with carbonic-acid gas at a temperature of 150° C. By the absorption of carbonic acid the basic sodium salt of salicylic acid results, and the former treated with hydrochloric acid produces salicylic acid.

Aside from its internal administration, salicylic acid is extensively used in surgery as a dusting powder for wounds (Schmidt), in solution (1 to 300) for the disinfection of wounds, and particularly for continuous irrigation, and in disinfecting ointments (one part acid salicyl., six parts cera alba, twelve parts paraffine, twelve parts almond oil). Salicylic acid should be used with caution as a dusting powder for wounds which are liable to absorb large quantities of it, since fatal poisoning has thus been produced. By adding borax to salicylic solution the solubility of the salicylic acid can be materially increased without diminishing the effectiveness of its action. A very useful solution for irrigation of wounds consists of one part salicylic acid, six parts borax, and five hundred parts water.

Acetate of Aluminium.—Acetate of aluminium, like all the salts of acetic acid, is a very good antiseptic (Pinner); Burow, senior (1857), was the first to use it with success. He prepared the substance from a mixture of eight parts acetate of lead, five parts alum, and sixty-four parts water, the acetate of lead being slowly added to the cold alum solution; this precipitated sulphate of lead, leaving the acetate of aluminium, though not chemically pure, in solution. The solution should then be filtered. Acetate of aluminium is used in the form of one-half- to one-per-cent. solutions for continuous irrigation and wet dressings.

Aceto-tartrate of Aluminium, an easily soluble double salt with a strong antiseptic action, is used in the strength of one half to three per cent. for antiseptic wet dressings, and in the strength of three to five per cent. for the disinfection of wounds (Schede, Kümmell).

Thymol, a non-poisonous substance, is the active principle of oil of thyme, which is obtained from various species of thyme, particularly the thymus vulgaris. In 1719, Neumann isolated from oil of thyme a crystalline, camphor-like body which he called thymol. The crystals are sparingly soluble in water, but readily soluble in alcohol and ether. Thymol is used in an aqueous solution in the strength of 1 to 1,000, containing, in addition to the water, ten parts of alcohol and twenty of glycerine to prevent the precipitation of the thymol.

Chloride of Zinc.—Chloride of zinc has been used by some surgeons for antiseptic dressings and disinfection of wounds. Weak solutions (2 or 2½ to 1,000), or stronger ones (1–5 to 100), have been used. It has not come into anything like general use in the treatment of wounds, and is chiefly employed as a caustic in about an eight- to ten-per-cent. solution to cleanse fistulous tracts, foul ulcers, etc.

Boric Acid.—Boric acid (H_3BO_3) exists in the form of flat crystals, which are only slightly soluble in cold water (1 to 30), but readily soluble in hot water and in alcohol. It is usually employed in a two- to three-per-cent. solution, though for irrigation of wounds aqueous solutions of a strength of 5–10 to 100 may be employed. Its antiseptic action is weak, and, if used too energetically, it is not without danger. Molodenkow observed, after ener-

getic irrigation of the pleural cavity and a psoas abscess with five-per-cent. boric acid, vomiting, erythema of the face, and death from cardiac paralysis in both cases. He used, it is true, a very large amount (fifteen kilogrammes) of a five-per-cent. solution, and the irrigation lasted an hour. Schuzer observed a fatal result in a patient who took fifteen grammes of boric acid for cystitis. He went into collapse a few hours afterwards, and died thirty-six hours later. The autopsy showed, besides a mild chronic nephritis, an acute toxic degeneration of the kidneys. The pre-existing chronic nephritis probably predisposed to the fatal result. Boric acid is much used in the form of Lister's boric lint, a dressing which is non-irritant and yet strongly antiseptic; it contains equal parts by weight of boric acid and lint, and is applied to the wound in a dry or wet state. Boric lint is very simply prepared by soaking lint in a hot concentrated boric-acid solution; it is then allowed to dry, causing the boric acid to adhere firmly to the lint in the form of crystals.

Boric Ointment.—An excellent ointment is made with boric acid consisting of three parts of boric acid, five parts vaseline, ten parts paraffine; or three parts boric acid, four parts cera alba, and twenty parts olive oil. A simpler and more stable mixture is one of twenty parts of boric acid with one hundred parts of vaseline or ungt. glycerini (known as glyceritum boroglycerini). Boroglycerin lanolin is another good preparation.

Aseptin.—The so-called aseptin used in Sweden is a mixture of two parts boric acid, one part alum, and eighteen parts of water; it is less irritating than carbolic acid, is not poisonous, and has no unpleasant odour.

Tetraboride of Sodium.—The tetraboride of sodium (Jaenicke) is more soluble and effective than boric acid, and on account of its non-irritant and non-poisonous character can be used in a fifteen- to seventy-per-cent. solution.

Bismuth.—Bismuth (subnitrate of bismuth) is a white crystalline powder of an acid reaction, which is only slightly soluble in water, and is recommended by Kocher for treating wounds and for antiseptic dressings. Bismuth lessens the secretion from a wound very perceptibly, but it is not an innocuous substance, as symptoms of poisoning have been produced when used in strong mixtures (ten per cent.) or in large amounts; these are acute stomatitis with marked swelling of the gums, tongue, and throat, and a dark discoloration of the edges of the gums, as in lead poisoning, diarrhœa, nephritis accompanied by albuminuria, and, finally, dark-coloured urine.

Iodoform.—Iodoform (CHI_3) is a bright yellow crystalline powder, almost insoluble in water, acids, and alkalies, but readily soluble in ether, chloroform, alcohol, volatile oils, and fats. About 2.5 to 3 grammes of iodoform are soluble in one hundred grammes of olive oil. It was first introduced in 1853, and since 1866 has been highly recommended as a dressing for wounds, particularly in syphilitic cases; but to Moleschott, and especially to Mosetig-Moorhof, belong the honour of introducing iodoform, in 1880, into general surgical use, and thus enriching our methods of dressing wounds by a most valuable remedy. Authorities differ as regards the antiseptic value of iodoform (see page

165). It is poisonous, and numerous fatal cases of poisoning have occurred from its use, particularly at first (see page 166). It should hence be employed with great care and not in too large amounts, especially in old, anæmic, or cachectic patients, in children, and in individuals with heart and kidney diseases. But even perfectly sound persons may have an idiosyncrasy as regards iodoform, and very small amounts may produce symptoms of poisoning. The crystalline form should be used, and not the fine powder, as the latter is absorbed more quickly and hence is more dangerous (Güterbock). I use iodoform to dust over unsutured wounds, particularly in tuberculosis and syphilis. It may be applied with a brush, or blown over or into the wound with a powder blower, or simply dusted over it through a piece of gauze. I consider it unnecessary to dust iodoform over a wound which has been sutured. It is very useful in injuries and operations affecting the nose, throat, mouth, vagina, and rectum, for syphilitic and tubercular ulcers, and for many cases of compound fracture.

P. Bruns and myself have obtained excellent results from the injection of a ten-per-cent. iodoform mixture in glycerine or oil, in cases of bone and joint tuberculosis and in cold (tubercular) abscesses. To avoid iodoform poisoning, the iodoform and oil or glycerine should be sterilised separately, and then mixed, because in sterilising the mixture at 100° to 130° C. in the steriliser too much free iodine and iodine hydrate are liberated. Glycerine, being itself aseptic, does not need sterilisation, and non-sterilised iodoform glycerine can consequently be employed without evil results. Schellenberg called attention to the possibility of glycerine poisoning in the use of iodoform glycerine injections. A child, four years of age, with suppurating hip-joint disease, died after the application of sixty to sixty-five cubic centimetres of glycerine, with the symptoms of fever, rapid pulse, coma, and marked signs of irritation of the kidneys. The amount that can be used safely in the case of children is about ten cubic centimetres, and in adults from twenty to twenty-five cubic centimetres. Iodoform kills tubercle bacilli slowly, and hence has a direct antitubercular action. Moreover, it brings about, both by internal and local use, fatty degeneration. It produces its action both by setting iodine free and by forming organic iodine compounds. Its action is to be regarded as a protracted iodine action (Högyer, Zeller, Harnack).

Iodoform has been mixed with other antiseptic powders. Sprengel recommends for cavities and bone and joint tuberculosis a mixture of equal parts of iodoform and calomel.

Iodoform gauze is exceedingly useful, consisting of iodoform 50, ether 250, alcohol 750, and gauze 500 parts; or iodoform 50, resin 20,

glycerine 5, and alcohol 1,000 parts. It is particularly valuable for packing cavities, but must be used with great care in the class of individuals mentioned above, as I have seen symptoms of poisoning after the use of iodoform gauze alone—for example, after extirpation of the rectum; and particular care must be taken not to exert too much pressure with the bandages applied over a wound which has been packed with this gauze. Billroth's sticky iodoform gauze is best suited for cavities where mucous membrane exists, because it adheres firmly to the surface of the wound. It is made by wringing out six metres of gauze or mull in a solution consisting of 100 grammes of resin, 50 grammes of glycerine, and 1,200 grammes of alcohol (95 per cent.), and after the gauze has dried, 230 grammes of iodoform are rubbed into it.

I sometimes use in place of iodoform gauze the iodoform wick recommended by Gersuny. It is prepared in the same way as iodoform gauze, and can be easily conducted out of the wound through a small opening in the skin.

An attempt may be made to conceal the very sharp, saffron-like odour of iodoform by the addition of tincture of musk, bergamot oil, tonka bean, or powdered coffee. Iodoformin and iodoformol are two odourless preparations of iodoform. Iodoformin, a white powder, is a compound of 75 per cent. iodoform and a formaldehyde. Kromayer recommends iodoformogen, an odourless iodoform-albumen preparation.

Iodoform Drainage Tubes, Iodoform Collodion, etc.—The impregnation of drainage tubes with iodoform has been recommended; they are soaked for about an hour in a concentrated solution of iodoform in ether and then allowed to dry. Iodoform is much used in the form of iodoform collodion (1 to 10), which is employed in place of the ordinary sticking plaster. Sticks of iodoform gelatine are now used for fistulæ, chronic gonorrhœa, etc. Mosetig recommends a fifty-per-cent. iodoform-glycerine injection for goitre and for soft hyperplastic lymphomata. Iodoform sticks are prepared according to the following formula: Iodoform 10 parts, gum arabic, glycerine, and starch, of each 1 part. They can be more simply made by mixing together one part of iodoform and two parts of cocoa butter. We shall return to this subject later on in its proper place. The iodoform-ethyl-alcohol solution (1 : 2 : 8) is used a good deal for parenchymatous injections into tubercular foci.

Effect of Iodoform upon Bacteria.—Kronecker, Heyn, Rovsing, and others, showed that the *Streptococcus* and *Staphylococcus pyogenes aureus* as well as other bacteria, may live a long time in iodoform powder unharmed. The growth and reproduction of tubercle bacilli, however, are diminished by iodoform and they gradually die. But although iodoform has no direct influence over most pathogenic bacteria, it is known that it weakens the tox-

ines of various bacteria, or changes the toxines into harmless compounds. Neisser showed that iodoform is decomposed by bacteria, and that it then has an antiseptic action. Of these decomposition products free iodine and hydriodic acid are the most important. The more pronounced the putrefaction and decomposition in a wound, the more pronounced becomes the antibacterial action of iodoform. According to Maurel, Lomey, and others, iodoform stimulates the phagocytic action of the leucocytes. Marchand and Meyer state that the formation of giant cells around a foreign body is diminished by the iodoform, and the cells of the exudate which have wandered into the foreign body are rapidly destroyed. Hence it is better to pack the wound with iodoform gauze than with sterile gauze, as the former does not adhere to the tissues and can be removed more easily.

Iodoform Poisoning.—The symptoms of iodoform poisoning consist chiefly of cardiac and cerebral disturbances, particularly in the severer cases. Cardiac symptoms are usually the first to make their appearance. The milder cases of poisoning are characterised by a rapid, irregular, small pulse; by digestive and slight nervous disturbances, such as anorexia, nausea, and finally vomiting; by headache, general malaise, sleeplessness, a depressed frame of mind, etc. In the more severe cases of iodoform poisoning the symptoms may correspond to either one of the two following descriptions:

(*a*) The pulse suddenly becomes rapid and small; there is sleeplessness, great restlessness, delirium, hallucinations, maniacal excitement, and melancholia, with refusal to take food. These symptoms of mental aberration can be quickly checked by removing the iodoform dressing, but they may be prolonged for weeks even after the iodoform has been stopped. Some of these cases terminate fatally from cardiac and respiratory paralysis.

(*b*) After a brief period of excitement there follows a general paralysis of the central nervous system, giving the picture of a severe meningo-encephalitis (loss of consciousness, deep sleep, coma, involuntary discharge of urine and fæces, accompanied by great muscular relaxation). This is the more severe form, and nearly always terminates fatally.

Occasionally there is observed a papular or, more commonly, an urticaria-like eruption on the skin. There is not always a rise in temperature. The pulse is usually greatly accelerated. The length of time that may elapse between the application of the iodoform dressing and the first symptoms of poisoning varies very much. Sometimes marked symptoms come on during the very day of the operation; in other cases three to five to six days, or even fourteen days, pass before they make their appearance. Iodoform poisoning is generally acute, but sometimes it takes a chronic or subacute course, and the symptoms may persist several weeks, although the drug is suspended at the very first appearance of intoxication. Mikulicz saw one case terminate fatally after the expiration of twenty-nine days. The majority of cases of iodoform poisoning have occurred in old people. In the latter all the organs, particularly the heart and kidneys, are less active, and consequently poisoning is more likely to occur. In children the danger of poisoning is much less.

Explanation of Iodoform Poisoning.—The symptoms of iodoform poisoning are due chiefly to the action of free iodine or of organic iodine com-

pounds. Iodine is set free at the point of application of the iodoform, and is absorbed by the blood in the form of alkaline iodide and the albuminate of iodine. The albuminate of iodine decomposes in the system, forming organic substances containing iodine, which are excreted in the urine together with the alkaline iodides. According to Harnack and Ludwig, the general symptoms of iodine poisoning are, in fact, chiefly produced by the iodine in the form of an albuminate of iodine, or by the organic compounds of iodine. It is well known that the alkaline iodides can be introduced into the system in very large amounts without causing the general symptoms of iodine poisoning. Zeller claims that only a fractional part of the iodine is excreted in the urine and fæces while the rest remains in the system; and thus he explains how iodoform poisoning may sometimes first make its appearance after the expiration of two to three weeks. If this substance is then employed in too large amounts, and circumstances favour its absorption, and if there is diminished excretion of iodine on account of disease of the kidneys or heart, while the blood is both qualitatively and quantitatively deficient, under such circumstances poisoning is apt to make its appearance rapidly and to run an acute course, terminating in death. As a means of preventing to a certain degree this general poisoning of the whole system, Harnack takes the precaution of applying with the iodoform some harmless alkali in the locality where the former is used, so as to favour the formation of an alkaline iodide from the free iodine which is split off from the iodoform.

Mosetig-Moorhof, in his large experience, has never seen a single case of iodoform poisoning, attributing it to the fact that he never uses iodoform except in small amounts, never applies dressings in which it exists so as to exert pressure, and changes them as infrequently as possible and without irrigation of the surface of the wound. He also considers it dangerous to use carbolic acid simultaneously with iodoform in dressings, because the carbolic acid may produce an inflammation of the kidneys amounting to an actual nephritis (nephritis carbolica), and thus retard the excretion by the urine of the iodoform which has been absorbed, or, in other words, cause it to be retained in the blood. These statements of Mosetig-Moorhof are confirmed by the experiments of Holger Mygind, who found that in all cases in which iodoform and carbolic acid were used together the iodine reaction was given in the urine rather later than usual, the longest time necessary for it to appear being twenty-seven hours after ingestion, the shortest four hours, or the iodine was detected in the urine only after all traces of carbolic acid had vanished. Moreover, Holger Mygind claims that the albuminuria that appears during the use of iodoform is only produced by the simultaneous use of carbolic acid. It is of some practical value to note that the excretion of iodine is continued for a considerable length of time after the use of iodoform has been suspended; for instance, one gramme of iodoform gave rise to a reaction for iodine for twenty-two days, and fifteen grammes gave the iodine reaction in the urine for thirty-eight days, etc. The size of the wound has a great influence upon the rapidity of the absorption of iodoform. Granulating wounds absorb it more quickly than fresh wounds, and wounds in which fat is abundant take it up very rapidly. According to Binz, the iodoform is dissolved by the small particles of fat.

As we have before remarked, iodoform produces marked cerebral and

cardiac disturbances, having a narcotic effect upon animals (dogs and cats), and causing death by paralysis of the heart and respiration (Binz, Hagyer). Aschenbrandt brought about a fatal pneumonia by causing animals to inhale iodoform vapour. The post-mortem examination in these cases revealed advanced fatty degeneration of the heart, liver, and kidneys. Post-mortem examinations of the human subject dying from iodoform poisoning reveal a similar fatty degeneration of these organs, and in addition either no change in the brain or an œdema of the pia mater.

Treatment of Iodoform Poisoning.—Besides the immediate removal of the iodoform dressing, *the treatment of iodoform poisoning* is purely symptomatic. In the worst cases no treatment has proved of any avail. Very alarming symptoms are apt to make their appearance suddenly without any prodromata. It is impossible to state the smallest amount of iodoform which may be used with impunity, as the dosage varies for each individual. One gramme of iodoform has been known to produce a transient delirium; and Seeligmüller observed melancholia with hallucinations thirty days after the administration of six grammes of iodoform; and five grammes caused the death of one of his cases, a woman thirty-six years of age. I lost one case in which a goitre was removed, and another in which a carcinomatous larynx was extirpated, in each of which cases I employed about five grammes of the powdered drug together with the iodoform in the iodoform gauze used for packing the wound. In still another case, a strong man fifty years of age, I saw alarming symptoms follow a simple dusting of the suture line after a laparotomy, with four to six grammes of iodoform; stupor, great restlessness, maniacal excitement, rapid, small pulse, etc., were present, but after four weeks complete recovery took place. Of course the dressings were removed at the very first appearance of the symptoms. The poisoning was doubtless caused by the excessive sweating to which the patient was subject during the hot days in July.

Detection of Iodine in the Urine.—For detecting iodine in the urine there are the following four methods:

1. The fluid to be tested is mixed with a little starch paste, dilute sulphuric acid, and a drop of fuming nitric acid, after which there results a bluish colour, which may change into dark blue according to the amount of iodine present. This colour disappears on warming the mixture, and reappears when it has cooled off again.

2. The fluid is mixed with dilute sulphuric acid and a drop of fuming nitric acid, and then shaken with chloroform, in which the iodine is soluble, producing a violet colour. Chloride of lime can be used instead of the nitric acid, and bisulphide of carbon instead of chloroform.

3. Upon the addition of equal parts of oleum terebinthinæ and guaiacol to an equal amount of urine there results a deep-blue colour if iodine is present.

4. To the fluid is added a little starch paste, dilute sulphuric acid, fuming nitric acid, and a few drops of bisulphide of carbon. The fluid assumes a blue colour, and if shaken, a part of the iodine is taken up by the bisulphide of carbon, producing a violet colour, and where the bisulphide of carbon touches the rest of the fluid a dark-blue ring of the iodide of starch gradually develops.

According to Harnack, this last test is the most delicate; but all these reactions are directly dependent upon the presence of iodine in the urine in the form of an alkaline iodide (iodide of sodium, etc.). He claims that iodine derived from the external use of iodoform occurs in the urine not only as an alkaline iodide, but also as a compound with organic substances, and in the latter state does not give the above reactions. Harnack noticed in two cases that the test for iodine in the urine was negative; but if the urine was evaporated and the residue burned, the ashes gave a very plain iodine reaction. His method is as follows:

The urine is rendered alkaline by the addition of sodium somewhat in excess, and evaporated in a platinum crucible in which the residue is then burned by heating the crucible red-hot. The carbonised ash is then repeatedly treated with hot water and the resulting extracts are filtered. To the filtrate is then added a few drops of dilute starch paste and fuming nitric acid, together with a few drops of bisulphide of carbon. When the solution is acidulated with dilute sulphuric acid the presence of iodine is indicated by a blue colour; when shaken, the bisulphide of carbon lying at the bottom takes on a violet tint, and just above it there forms a dark-blue ring of the iodide of starch. To recognise the difference between the intensity of the reaction obtained from the ash and from the urine, the former must be mixed with a volume of water equal to the amount of the original unevaporated urine, and then the reaction is carried out with equal quantities of this mixture and of urine.

Substitutes for Iodoform.—The following preparations have been recommended as substitutes for iodoform: Iodoformin, iodoformol, iodoformogen (see page 165), iodol, salubrol, salol, europhen (containing 28.1 per cent. iodine), aristol (a combination of iodine and thymol), loretin (a non-poisonous, yellowish crystalline powder), xeroform (tribrom-phenol-bismuth), salubrol (tetrabrom-methylen-di-antipyrin), amyloform (chemical compound of formaldehyde with starch, nosophen (eudoxin, tetra-iodo-phenol-phthalein), sanoform (diiodo-salicylic methyl-ester), etc. Aristol has no odour and is non-poisonous, and is particularly useful in the treatment of various skin diseases. Pallin saw a case of iodol poisoning after the use of five grammes of this substance in a sequestrotomy of the clavicle. Salol should be given internally with caution, on account of the phenol it contains; Hesselbach observed a death follow the administration of eight grammes of this drug, which parted with about 3.04 grammes of carbolic acid in the body.

Dermatol is an excellent non-poisonous substitute for iodoform, and much used in the treatment of skin diseases. The cases of poisoning from dermatol which have been reported by Weissenmüller and others were probably caused by the use of an impure preparation (arsenic?). Haegler recommended airol, a compound of dermatol with iodine. Among the newer antiseptic powders diiodthioresorcin,

sulphaminol, nosophen, and sozoidol are particularly well spoken of. The latter non-poisonous powder is used in the form of a one-per-cent. emulsion in glycerine, gum arabic, and water, also in the form of an ointment, and for catarrhal conditions, etc.

Of the remaining antiseptic substances, of which there are a great number of considerable merit, I shall briefly mention the following:

Orthoform is a white, non-poisonous, odourless, and tasteless powder, which, on account of its prolonged anæsthetic action and its capability of diminishing secretions, is used a good deal for burns, ulcers, and venereal sores, and internally for ulcer of the stomach, etc.

Naphthalin.—Naphthalin ($C_{10}H_8$) was isolated from coal tar by Gardener in 1828. It forms large, shining, colourless, crystalline plates of a tarry odour and a burning taste. It is insoluble in water, readily soluble in hot alcohol, ether, volatile and fixed oils. It burns with a bright, sooty flame.

Naphthalin is dusted over a wound in the same way as powdered iodoform. In my own experience I have found naphthalin a most excellent disinfectant. A foul wound will quickly clean up after dusting it with naphthalin, and the process of granulation is accelerated. Sometimes, however, its use is accompanied by pain.

Benzoic Acid.—Benzoic acid crystallises in the form of thin plates or needles, which are only slightly soluble in cold water (1 to 500) but readily soluble in hot water (1 to 30), and in alcohol, ether, and concentrated sulphuric acid. Benzoic acid is usually employed in solution in the strength of 1 to 200.

Sulpho-carbolate of Zinc.—Bottini (Pavia) has recommended sulpho-carbolate of zinc as an antiseptic. It forms large, white, transparent, odourless, rhomboidal crystals, which are readily soluble in distilled water, alcohol, and other liquids. Bottini considers the sulpho-carbolate of zinc better than all other similar antiseptics. It has the great advantage of being absolutely non-poisonous. It is employed in two- to ten-per-cent. solutions.

Alcohol.—Dressings of alcohol have been used since the most ancient times, and were in great repute even in Heister's day. In France, and perhaps in England, this liquid finds its most extensive use. Fifteen- to twenty-per-cent. solutions have been used for washing out wounds and for disinfecting instruments, sponges, etc. Salzwedel recommends a dressing of ninety-six per cent. purified alcohol in the treatment of cellulitis, abscess, lymphangitis, felon, and furuncle. His dressing consists of the following three layers: (1) a thick layer of gauze soaked in alcohol, (2) dry cotton, and (3) perforated rubber tissue. Other surgeons have also found alcohol dressings useful. According to Hack, it has the effect of rendering granulations which have been treated with it incapable of absorbing anything.

Terebene.—Terebene ($C_{20}H_{16}$) is a brownish oily fluid with a pleasant, aromatic odour, insoluble in alcohol, ether, water, etc., but soluble in all proportions in oil. It is much used, particularly in England, for the treatment of wounds, either in the undiluted form for badly granulating, foul, gangrenous wounds, or diluted with equal parts of oil for the saturation of dressings, or else it is mixed with water (30 to 500) and used for irrigation purposes.

Eucalyptus.—Eucalyptus is a volatile oil having a strong antiseptic action, and is made from the leaves of the myrtaceæ, a tree growing in Belgium, Italy, and the south of France (the *Eucalyptus globulus*). It has been recently recommended by Schultz as an excellent non-poisonous antiseptic. The commercial article is very variable in quality, and Schultz advises that the oil be treated with soda until its acid reaction becomes neutralised, and then be exposed in sunlight to the action of the oxygen in the air, which causes the oil to lose its pungent odour and become non-irritating when used in dressings. The oil of eucalyptus can be mixed with alcohol and water, 0.2 to 0.3 per cent., and then used as a fluid in which to wring out compresses. Lint which has been soaked in a solution of one part oil of eucalyptus and ten parts olive oil can be used for applying to wounds.

Iodine.—The antiseptic properties of iodine, tincture of iodine, the solution of iodine in an aqueous iodide of potash solution and of iodine vapour, have been proved by countless experiments. In recent times, in England and America, the solution of iodine—i. e., iodine two parts, iodide of potassium three parts, and water forty-eight parts, has been used for dressings, lint being steeped in this mixture. The combination of this iodine solution with laudanum is also highly spoken of. For cleansing wounds, Bryant recommends iodine water (one part tincture of iodine to 75 to 100 of water).

Trichloriodine.—Langenbuch recommended trichloriodine (1 to 1,000–1,500) as practically devoid of danger, and as a suitable material for the disinfection of the instruments, hands, the field of operation, sponges, etc., and he tested it in a great number of cases. In germicidal power it stands next to bichloride of mercury (Riedel).

Creolin.—Jeyes, its discoverer (1875), Kortüm, Fröhner, and others, recommend creolin in a one- to two-per-cent. solution, which, according to Henle, is a mixture of soap, oil of creolin, phenol, and pyridin; it combines the useful properties of bichloride of mercury and iodoform without their poisonous effects. Creolin is an oily, dark-brown fluid, smelling of tar, and is made by the dry distillation of coal tar, forming with water a milky emulsion which has a threefold more powerful action than carbolic acid, and is used in a one- to two-per-cent. solution. Esmarch has given fifty grammes of creolin to animals internally without causing any bad effects. Behring, Baumgarten, etc., maintain that creolin has no such germicidal properties as carbolic acid or bichloride of mercury, and that it is more poisonous than has been hitherto supposed. In severe cases of creolin poisoning—for example, after the internal administration of large amounts—there occur loss of consciousness, albumen and blood and renal epithelium in the urine, enlargement of the liver, and jaundice (van Ackeren).

Tricresol, in a one-per-cent. solution, is said to correspond in its action to a three-per-cent. carbolic solution. Cresolum purum liquefactum is used by some in place of carbolic acid. Formalin (formaldehyde) has been used a great deal of late for the sterilisation of the hands, the field of operation, etc.

Peroxide of Hydrogen.—Peroxide of hydrogen (two- to three-per-cent. solution) is rather expensive, and on account of its unstable character it is unsuited for an antiseptic.

Rotter's Antiseptic Solution.—Rotter has combined a great number of antiseptics in one solution. To one litre of water are added bichloride of mer-

cury 0.05 gramme, sodium chloride 0.25 gramme, carbolic acid 2.0 grammes, chloride and sulpho-carbolate of zinc, each 5.0 grammes, boric acid 3.0 grammes, salicylic acid 0.6 gramme, thymol 0.1 gramme, and citric acid 0.1 gramme. The ingredients of this solution are also combined in tablet form, and called "Rotterin." Rotter also left out of this solution bichloride of mercury and carbolic acid, and considers that the remaining ingredients have a stronger antiseptic action than one-tenth-per-cent. solution of bichloride alone. Beyer has demonstrated that all these different antiseptics combined in the one solution do not undergo any change.

Aniline Dyes.—Stilling recommends the aniline dyes for antiseptics in the form of an aqueous solution of (pyoktanin, Merk.) methyl violet (1 to 1,000), but its value has not been confirmed by others (Carl, Jaenicke, Petersen, etc.).

Lysol.—Lysol in one fourth- to two-per-cent. aqueous solution, manufactured by Schülke & Mayer, in Hamburg, is an excellent and relatively non-poisonous antiseptic, and is recommended by Engler, E. Schmidt, Gerlach, etc., and has been much used in operations. On account of its cheapness and its non-poisonous character lysol is very well adapted for disinfecting and cleansing purposes, instead of carbolic acid.

Solveol.—Solveol (Hammer, A. Hiller), a cresol compound (neutral aqueous solution of creosol) in 0.5-per-cent. solutions, has a more powerful antiseptic action than five-per-cent. carbolic solutions, and it is, furthermore, comparatively non-poisonous.

Ichthyol.—Ichthyol is extensively used in the treatment of erysipelas and other skin diseases. Latteux commends the antiseptic effect of five- to ten-per-cent. solutions for irrigating purposes.

Alumnol.—Alumnol (Heinz, Liebrecht) is a white powder which is highly recommended for the treatment of skin diseases and gonorrhœa, and in one-half- to two-per-cent. solutions for the disinfection of cavities, abscesses, infected wounds, ulcers, etc. Cauterisation with a ten- to thirty-per-cent. solution is useful for cleansing ulcers.

Tumenol has been recommended by Neisser for the treatment of erosions, excavations, ulcers, eczema, and other skin diseases.

Teucrin.—Mosetig-Moorhof reports good results from injections of teucrin for local fungous lesions. It is an extract of teucrium scordium, which has a marked action on the vasomotor nerves.

Preparations of Silver.—Silver is an excellent antiseptic, and Credé has developed a method of treating wounds with silver preparations which is based on exact bacteriological experiments. He covers sutured and open wounds with his silver gauze and dusts itrol (argentum citricum) over punctured wounds. The silver gauze contains metallic silver in a very finely divided form; it is absolutely non-irritating, and develops an antiseptic action in a wound as soon as germs make their appearance, because the latter produce lactic acid which forms lactate of silver, a strong antiseptic. Itrol and actol (argentum lacticum) are used in solutions of 1 : 4,000–8,000 for irrigation. As actol is absolutely non-poisonous, Credé uses it internally in sepsis and pyæmia. He also impregnates silk, catgut, and drainage tubes with silver. The stains on the linen produced by the silver salts are easily removed, even when old, by placing the stained linen for a few minutes in a solution of 1 gramme bichloride, 2,000 grammes water, and 25 grammes

sodium chloride. It is then thoroughly rinsed off. Credé succeeded in preparing silver that is soluble in water. He recommends this solution of metallic silver (0.5-per-cent. solution) both for internal use and for subcutaneous or intravenous injections. He also uses an ointment containing metallic silver for inunctions, in cellulitis, lymphangitis, septic intoxication, scarlet fever, diphtheria, etc. It is not yet possible to give a correct opinion of the internal antiseptic values of silver, as the number of observations is too small. In some cases I have seen surprisingly good results, and in others they were negative. Unguentum Credé contains fifteen per cent. of silver.

Other Antiseptics.—There are still to be mentioned alum, quinine, chloral (one to four per cent. in water), chloroform water (Salkowski), chloride of lime, carbonate, acetate, and chloride of lead, acetic acid, permanganate of potassium (from 1 : 1,000–100), camphor, and the spirits of camphor, glycerine, sugar, sulphate of zinc, oxide of zinc, citric acid, trichlorphenol (one- to ten-per-cent. solution), turpentine, tar, peroxide of hydrogen, sulphuric acid, and the sulphates and subsulphates of the alkalies, picric acid, resorcin, balsam of Peru, styron (one per cent.), charcoal, powdered coffee, naphthol (soluble in 5,000 parts of water, but more soluble by the addition of alcohol), tannic acid, chromic acid, bichromate of potassium, aseptol (two- to ten-per-cent.), aseptic acid (five- to ten-per-cent. solution), etc.

§ 47. **Which Antiseptics and which Antiseptic or Aseptic Dressings are the Best?**—Which antiseptic among the great number which are recommended is the most powerful and at the same time the best adapted to the treatment of wounds? My own experience places carbolic acid and bichloride of mercury at the head of the list for certainty in action, and if used with caution, particularly in the case of children and cachectic individuals, they are also devoid of danger. For aseptic operations common salt solution or simply sterilised water may be used. Among the other antiseptics the ones which I consider the best are boric acid, acetate of aluminium, creolin, lysol, salicylic acid, iodoform, oxide of zinc, and dermatol. The method of their application has been sufficiently described above.

Which antiseptic or aseptic material is the best for dressings? Their number is almost without limit, and the choice, as we have remarked, is more or less a matter of taste. But the great principles involved remain the same, namely, that the operation must be conducted with the strictest attention to asepsis and that the arrest of the hæmorrhage, the drainage, and the suturing of the wounds should all be carried out with the greatest care. The fate of the patient who has been operated upon depends very largely upon whether the operation has been performed aseptically or not. The dressing that is put on the wound has no longer the importance that was at one time ascribed to it. It should consist of freshly sterilised material which has good absorptive power (gauze, cotton, moss, wood wool, paper

wool, etc.). Moss, wood wool or excelsior, jute, etc., are covered with sterilised gauze and applied in the shape of sterilised pads or cushions. All materials used for dressings should be sterilised by steam at a temperature of 100°–130° C. for twenty to thirty minutes in a steam sterilising apparatus. Dressings which have been impregnated with antiseptics become after a time less aseptic, and, furthermore, produce irritation of the skin and cause an eczema (see pages 3, 4). My own method of applying a dressing is very simple, and is ordinarily done as follows: The wound, or the suture line, is covered with several layers of sterilised gauze or iodoform gauze; over this is placed cotton which has been sterilised by steam at a temperature of 100° C. (212° F.). The less the wound is irritated by antiseptics, or, in other words, the dryer the operation, so much the less is the subsequent secretion from the wound, and there is consequently less need of dressings having great absorptive powers like moss pulp, wood wool, etc.; gauze covered with absorbent cotton or jute cushions will be all that is required.

To favour the drying of the secretion from the wound within the dressings the gutta-percha or mackintosh should be avoided, except in the case of young children, when some water-tight substance should be employed to prevent the dressings from becoming soiled by urine, fæces, etc. In small children I often dispense with the dressing. All the dry antiseptic dressings are much better than those of the wet antiseptic, occlusive variety, as the latter are apt to occasion an eczema frequently lasting a good while, and increase the danger of poisoning, particularly from carbolic acid and bichloride of mercury. But, as we shall see, wet dressings are sometimes most excellent for contused and suppurating wounds. I never apply antiseptic dusting powders, like iodoform, bismuth, salicylic or boric acids, to a wound which has been closed by sutures. This powder dressing is chiefly suited for wounds which have not been closed by sutures and for those which are granulating or suppurating. Open wounds are often packed with sterile or iodoform gauze and then closed by secondary sutures from two to four days after removal of the packing. I attach great importance to the use of a moderate amount of pressure upon the wound, particularly after the extirpation of tumours. For this purpose the gauze is folded up so as to make a pad. Antiseptic sponges have also been employed with good results for exerting pressure on wounds. For an ointment I prefer boric acid or plain vaseline. For covering the suture line and touching up superficial erosions, granulations, etc., I often make use of zinc glue or bismuth paste (bismuth stirred up in a little bichloride). If it is necessary to disinfect an already infected wound, I use solutions of bichloride of mercury (1 to 1,000–5,000).

The antiseptic and aseptic dressings should be as large as convenient, though I do not consider this now of as much importance as I used to. Aseptic operation wounds, for example, after a laparotomy, may simply be covered with collodion or bismuth paste. For applying the dressing the patient should be placed in the most suitable position. For bandaging the head, shoulder, and thorax the patient should be made to assume a sitting posture, while for the abdominal region one or more cushioned props (Fig. 142) are placed under the patient while the legs are held by an assistant. Splints of wood, sheet metal,

Fig. 142.—Support for the pelvis (Volkmann).

Fig. 143.—Aseptic dressing for the scalp.

Fig. 144.—Aseptic occlusive dressing for the head, neck, and chest.

plaster of Paris, or wire, etc., serve to immobilise an extremity (see § 53). For less serious cases thin, pliable wooden hoops are exceedingly useful. One of the great advantages of the antiseptic and aseptic methods of treating wounds lies in the fact that the dressing requires much less frequent renewal than formerly, when the unsatisfactory occlusive dressing was employed.

Figs. 143 and 144 illustrate two methods of applying an aseptic dressing to the skull and the head, neck, and chest. The particulars are given in § 50.

§ 48. **The Changing of an Antiseptic or an Aseptic Dressing.**—When shall an aseptic dressing be changed? In the first place, the nature of the case and the kind of operation or injury must be considered.

In general it has been my experience that a change of the dressing called for under the following conditions:

1. When the temperature rises above 38.5° C. (101.3° F.).

2. When the dressing becomes soiled from without—for example, by urine or other excretory matter.

3. When the patient is suffering severe pain.

4. When the dressing becomes displaced or loosened, or when the secretion from the wound has saturated the dressing.

Whenever fever occurs—and I make a regular practice of considering any rise of temperature above 38.5° C. (101.3° F.) under this heading—I change the dressing, and am pretty sure to find that there is either some slight disturbance in the wound, a retention of the secretion, or a stitch which is too tight, etc. As a general thing, in my own operations I have very seldom observed any rise in temperature above 38.4° C. (101° F.). Other surgeons have noticed a rise of temperature of several degrees during the healing of a perfectly aseptic wound. Volkmann and Genzmer, especially, have made investigations upon this fever and have called it the "aseptic-wound fever." I have very seldom seen the aseptic-wound fever, and when a rise in temperature does occur while the healing process is going on it will usually be found to take its origin from some perceptible abnormity in the wound. Opinions vary as to the cause of this aseptic-wound fever. Volkmann and Genzmer consider it an absorption fever produced by the entrance into the general system of the relatively homologous products of metabolism and disintegration which are formed in every wound. Sonnenburg and Küster believe that aseptic-wound fever is caused by carbolic-acid poisoning. Both of these views are of use in explaining the phenomena. My own view of the aseptic-wound fever leads me to believe that it is caused by the absorption of lymph and the fibrin ferment from the blood lying in the wound. This fibrin ferment is formed the more abundantly the more the wound has been irritated by carbolic acid or other strong antiseptic solutions. I believe I am not mistaken in affirming that all surgeons who make free use of solutions of bichloride, carbolic, or other irritating antiseptics in their treatment of wounds, will frequently notice aseptic rises in temperature, while those surgeons who are cautious in their use of antiseptics, and prefer asepsis to antisepsis, will only observe this phenomenon in a few exceptional cases. Many surgeons—Neuber, for instance—have recommended that the dressing be allowed to remain undisturbed in such instances of aseptic fever, claiming that a change of dressing only creates further disturbance in the wound, and is consequently harmful. I cannot agree to this statement, though I seldom have to do with fever following an operation. If it does occur, always change the dressing as a matter of course, if the temperatur

rises above 38.5° C. (101.3 F.), and I usually find, as I have said, some slight variation from the normal in the healing process. I prefer to change the dressing as infrequently as possible, and I am particularly careful to avoid irritating the wound by excessive irrigation, washing out, etc. It can only do harm.

From what has been said so far, we can readily understand the importance of ascertaining a patient's temperature in the morning and evening, or, in more important cases, three to four times a day, or even every two hours, and it is best taken in the rectum. I prefer, if there is fever, to change the dressing too frequently rather than allow one to remain too long. If the discharge should soak through the dressings, they can still be left undisturbed, if only the external layers remain dry and no fever is present. Additional layers of dressing may be placed on the outside, if necessary.

My rules for changing an antiseptic dressing are as follows: If the wound is large, and there is considerable discharge, I change the first dressing after the expiration of twenty-four to thirty-six hours, even though there is no rise in temperature; or I allow the first antiseptic dressing to remain undisturbed till the end of the third to the fourth to the eighth day, according to the nature of the case. Drains are removed at the end of the first twenty-four hours, or on the second to the third day, the stitches generally on the third to the fifth day. After a laparotomy which runs a normal course without reaction, I change the first dressing on the eighth to the twelfth day, according to the size of the abdominal wound, and at the same time I remove the stitches, though if the wound is under considerable tension a stitch here and there is left in place for a little while longer.

An aseptic dressing should be changed only with the strictest attention to the rules of antisepsis, and everything which is required for the dressing, particularly the gauze, bandages, etc., is to be prepared in advance in the proper manner. The instruments, such as scissors, probes, forceps, etc., should be boiled in a one-per-cent. soda solution and placed in a sterile soda or salt solution; the sponges or gauze pads should lie in a one-tenth-per-cent. solution of bichloride or in salt solution. The hands are to be disinfected with the greatest care (see page 10). The dressing is then slit up with strong bandage scissors (Fig. 145), or the bandage is unwound, and after it has been thoroughly washed, disinfected, and sterilised by steam at 100° C., it may be used again as a non-antiseptic bandage; but it is

Fig. 145.—Bandage scissors.

a better plan to burn all dressings immediately after they have been taken off. I never use the carbolic spray now.

After removing the bandages and superficial portions of the dressing, the hands are again disinfected, and then the portion of the dressing lying in contact with the wound is removed as carefully as possible. If it adheres to the skin or to the wound, it should be softened by squeezing out upon it a few drops of the antiseptic solution or sterile salt solution. The wound is then examined by pressing here and there very lightly with the index and middle fingers to ascertain whether there is any retention of the secretion, and finally the drains, stitches, etc., are removed. If the healing process is progressing normally in every respect, there should be no syringing out or washing off of the wound, and all that is necessary is simply the application of a fresh dressing. The forcing of antiseptic solutions through the drainage tubes is particularly to be avoided, as it always does harm, and I never indulge in this practice except when suppuration is present, and then only rarely. If the drains become occluded by blood-clots and are to remain in the wound, they should be made pervious by passing a probe through them; or, better still, they should be taken out of the wound, washed in a three-per-cent. solution of carbolic or 1 to 1,000 bichloride, and finally reinserted with a safety pin attached to them to prevent them from slipping into the wound, or else entirely new drainage tubes may be employed. Very often a stitch which is cutting into the tissues or is drawn too tight must be removed at the end of twenty-four to thirty-six hours. The presence of swelling and redness indicates a retention of the secretion, which should then be let out by one or more incisions with the knife, with or without subsequent drainage. If there is an appreciable amount of suppuration it may be necessary in some cases to change the dressing every day for a time, or to substitute for the antiseptic occlusive dressing some other simpler kind. Should erysipelas occur, the employment of ichthyol is to be recommended, and the antiseptic occlusive dressing can be maintained.

Even when the wound remains uninterruptedly aseptic, bacteria are commonly found in the antiseptic or aseptic dressings. These bacteria belong chiefly to the non-pathogenic species of skin coccus, and do not interfere with the normal process of healing. If the *Staphylococcus pyogenes aureus* and the *Streptococcus pyogenes* are found, there will probably be a disturbance in the wound, but the presence of the *Staphylococcus pyogenes albus* only exceptionally causes an infection of the wound (Tavel, O. Lang, A. Flach). Dressings which have been allowed to remain in place a long time will give off a bad odour not unlike old

cheese, caused ordinarily by the decomposition of sweat and sebaceous matter. Not infrequently there will be found an eczema, especially if wet carbolic or bichloride dressings have been used, and this is best treated by the application of vaseline or the ungt. lithargyr. Hebræ,* and by dusting it over with bismuth and starch (1 to 5–10 parts), or oxide of zinc and starch (1 to 5–10 parts), or by applying Lassar's paste (oxide of zinc and powdered starch āā 10 parts, salicylic acid 1 part, vaseline 20 parts). Such eczemas can be best avoided by the use of simple, sterilised, dry dressing materials.

Eczema of the Surgeon's Hands has become less common since the introduction of asepsis, but it does occur in those predisposed to it, and not always at the beginning of their surgical career. It is a good plan for such persons, after sterilisation of the hands, to anoint them while still wet with a sterile greasy material (e. g., olive oil, glycerine, lanolin, and vaseline, equal parts, into two per cent. resorcin). Eczema is treated in the same way. Lassar recommends the use of tar oil with alcohol at night. The hands are then washed half an hour later with soap and water, and then covered overnight with two per cent. salicylic paste or zinc-oil paste (60 parts zinc oxide, 40 parts olive oil). Before applying the tar the following paste can be used (Lassar): β-naphthol 10, sulph. subl. 40, sapon. virid. and vaseline āā 20 parts. Then ten to fifteen minutes later twenty-five per cent. chrysarobin in lanolin is applied, and in ten to fifteen minutes more the tar. Rotter recommends for moist eczema, formalin 0.25–0.5, zinc oxide and talcum āā 25 parts, vaseline 50 parts. It is sometimes necessary to stop surgical work for a time. The action of the different remedies is very variable. Sometimes the best remedies are used in vain, and then suddenly one may be helped by simply using hot water, and another by cold water or an ice bag, painting with egg albumen, etc.

If the wound has healed there is generally no further need of any dressing. In other cases it may be necessary to cover granulating areas or drainage holes with some ointment like boric-acid ointment, or by sticking plaster, iodoform collodion, or with iodoform, zinc oxide, or bismuth powder, or with a piece of simple dry gauze or cotton. Bismuth-bichloride paste, made by simply mixing bismuth with a little bichloride solution, forms an excellent, rapidly drying scab, and I use it a good deal in place of adhesive plaster. I very often allow an aseptic material which has become dry to remain on the wound like a scab, with or without a protecting bandage. After a time the aseptic scab drops off and the wound is found to be healed.

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* Unguentum diachylon.

CHAPTER II.

OTHER METHODS OF TREATING WOUNDS.

The old-fashioned protective dressing.—Open method of treating wounds.—Healing beneath a scab.—Antiseptic bathing.—Immersion.—The use of warm baths.—Cataplasms.—Poultices.—Cold.—Ice.—Leiter's cooling apparatus.—Adhesive substances (sticking plaster, gauze adhesive plaster, English plaster, collodion, photoxylin, traumaticin, gummi laccæ).—Ointments.

§ 49. **Other Dressings for Wounds.**—The old-fashioned protective dressings of sticking plaster, charpie, ointments, etc., are no longer used at the present day, and after operations we now cover the wound, without exception, with antiseptic or aseptic dressings, though in the case of small fresh wounds, or those which are granulating, we occasionally employ adhesive plaster, collodion, iodoform collodion, and antiseptic salves, boric-acid ointment, for example.

Open Method of treating Wounds.—The open method of treating wounds is the simplest one of all. Small superficial wounds are now allowed to go without any dressing, especially when the blood and secretion from the wound becomes dried and thus forms a protecting crust beneath which the wound heals.

Healing beneath a Scab.—The healing under a scab, which occurs in small wounds, has been made the basis of a separate method of treatment, in which an attempt is made to form a scab artificially over wounds having an abundant secretion by the application of dry substances, such as tinder and various kinds of powders, or a dry eschar is made by some strong caustic, like nitrate of silver, liq. ferri sesquichlor., the hot iron, etc. All these different ways of accomplishing the same result, if carried out with no antiseptic precautions, even though the wound be small, are not devoid of danger. But the modern surgeon never fails to treat every wound, including the very smallest, upon antiseptic principles, because we know that even the most insignificant lesion in the skin, under certain conditions, may cause a septic cellulitis or an erysipelas which can prove fatal. On the other hand, Schede's method of treating wounds by permitting a moist aseptic blood-clot to remain (see page 109) is to be looked upon as a real advance in this branch of surgery. As above stated, it is an excellent plan to permit the dried

essings to remain upon the wound like a dry aseptic scab, until they me away of their own accord when the wound has healed.

This open method of treating wounds yielded relatively excellent results the preantiseptic days of surgery, even when used for large wounds, such amputations, disarticulations, compound fractures, etc., and was practised ll supplanted by the antiseptic dressing.

In the open method of treatment the wound was not provided with any lressing, but left entirely exposed, or only lightly covered with antiseptic compresses. It was not closed with sutures until later on, when a few coaptation sutures were used. In this way the escape of the secretion from the wound was favoured. If the wound was situated on an extremity, the latter was placed in a proper position to facilitate the escape of the discharges, which were received in a vessel or bowl placed beneath. The crusts which formed in the wound, from dried blood or secretions, were softened and removed by means of antiseptic solutions or by carbolised oil. The principal advantages in the treatment of a wound by the open method were a ready escape of the secretions, complete rest which was undisturbed by change of dressings, and finally absence of pressure. It had the disadvantage that wounds healed slowly and only after suppuration.

In cases where the antiseptic occlusive dressing is no longer advisable on account of suppuration, or a threatening systemic infection, when it may even become dangerous from the pressure it exerts, the open method of treating wounds, particularly in conjunction with continuous antiseptic irrigation, is now in very general use, and is an exceedingly valuable means of handling these cases.

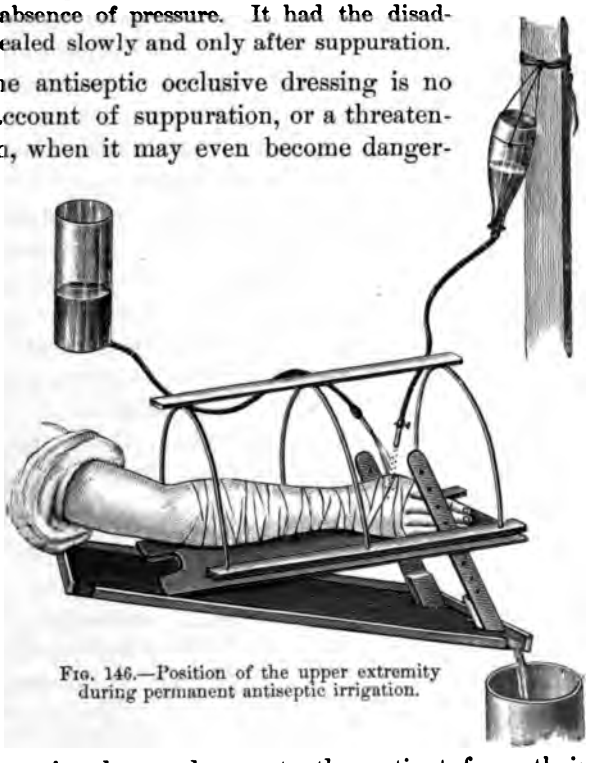


Fig. 146.—Position of the upper extremity during permanent antiseptic irrigation.

Continuous Irrigation.—For continuous antiseptic bathing of a wound, or, in other words, for continuous irrigation, such antiseptic solutions should be used as involve no danger to the patient from their absorption and produce no symptoms of poisoning. Of these, the best are three-tenths-per-cent. solutions of salicylic acid; the boro-salicylic solution (1 part of salicylic acid, 6 of borax, and 500 of water); or solu-

tions of one tenth per cent. thymol, four per cent. boric acid, one ha to one per cent. acetate of aluminium, or, what is the best solution (all, viz., Burow's (described on page 162), consistin of ten per cent. subsulphate of sodium, one tenth pe cent. permanganate of potassium, lysol, etc. Th wound is covered with a light gauze compress. Th patient is made to assume a suitable position, an protected by means of water-tight coverings and als by properly regulating the overflow of the irrigatio fluid. The solution is made to drip from an Es march irrigator placed in some elevated spot, o from an improvised irrigator, such as an inverte champagne bottle from which the bottom has bee partly removed (Fig. 147), or the excellent apparatu of Starcke may be used (Fig. 148). Fig. 146 illustrates the proper position for the upper extremit when continuous antiseptic irrigation is employed Starcke's apparatus consists of a vessel for holdin fluid which is connected by a rubber tube with lead or glass pipe; this is fitted with numerous out lets also connected with rubber tubes which can b opened or closed by stopcocks or clamps, and b means of wires in their interior can be bent an turned in any desired direction. The lead or glass pipe is suspende from some beam or support by a couple of strings.

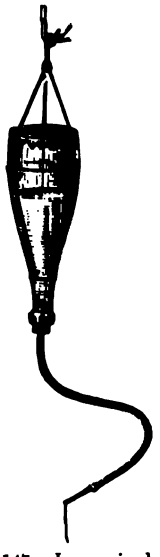


Fig. 147.—Improvised apparatus (irrigator) for the irrigation of a wound.

If Esmarch's irrigator or the inverted champagne bottle are use as in Fig. 147, the fluid is made to escape in drops or in any require amount by means of a stopcock placed at the point of insertion of the rubber tube. If the tube is not fitted with one, the outflow of fluid can be regulated by a clamp, or a piece of cotton, or a few strands of jute stuffed into the lumen of the tube, or by a straw, etc.

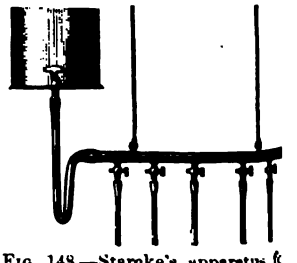


Fig. 148.—Starcke's apparatus f the irrigation of a wound.

Immersion.—Immersion, or bathing of the whole body, or separate portions of it which have sustained an injury, is in many cases indispensable. The continuous immersion of a patient's whole body in a warm bath day and night adapted especially for gangrene, extensive burns, cellulitis, bedsore urinary and fæcal fistulæ, and for the after-treatment of operatio on the rectum, bladder, urethra, etc. The bath tub is usually made

ntain a framework of wood or metal fitted with slats and a movable eadpiece which can be raised or lowered. Covers are laid over the rame and an air cushion on the headpiece, and thus the patient is nade very comfortable. The patient can be placed on an ordinary heet instead of a frame, and in this way can be raised or lowered in he tub. The temperature of the water must not be allowed to become too cool, and it is best to regulate it according to the wishes of the patient, and therefore it is a good plan for him to be able to regulate the temperature of the bath himself by turning on or letting out the water. The temperature of the water must usually be maintained at 37° to 38° C. (98.6° to 100.4° F.), and perhaps more, and of course the patient, while asleep, should be watched very carefully by a nurse.

Influence of a Continuous Bath on a Wound.—The influence of prolonged baths of this kind upon a wound is in general very favourable. The granulations usually swell considerably, and it occasionally happens for this reason that the escape of the discharges is rendered difficult, causing retention and burrowing of pus and phlegmonous inflammations. The wounds should hence have thorough drainage. Nevertheless, the freely granulating surface is apt to become covered with skin very rapidly, and the parts surrounding the wound become soft and yielding. For stimulating the growth of the granulations, irritant substances, like spirits of camphor, etc., have been added to the bath, or the wounds have been dressed with them. If the bath becomes too cold there is a possibility of necrosis taking place here and there in the skin; and care should be taken in subjecting old people to prolonged baths on account of the danger of pulmonary, cardiac, or cerebral disturbances. In extensive fresh burns also baths should be used cautiously, as the warm water lowers the vascular tone, and in this way cardiac paralysis may result. The bath is very much to be recommended during the stage of suppuration.

The use of baths for separate portions of the body which have been injured needs no further description.

Cataplasms.—Warm poultices, either dry or wet, were much used in the treatment of wounds during the preantiseptic days. Fomentum, a hot, wet application, or a fomentation as it is called, is derived from *foveo*, to warm. Cataplasm, or poultice, comes from the Greek word καταπλάσσω, to lay on. Cataplasms or poultices are made of boiled linseed meal, groats, etc., which re inclosed in gauze or linen cloth before applying. At present cataplasms re not considered proper for the treatment of wounds, and we only use hem when we desire to promote suppuration in tissues which are infiltrated ith inflammatory matter. The preparation of poultices is very tedious. he hot poultice is renewed by warming the wet cushion upon a hot plate, in vessels made for the purpose with double walls between which the

water is placed to supply the moisture, and the vessel is then heated over a gas or spirit-lamp flame. For doing away with this slow process there have recently been invented artificial cataplasms about the weight of thin pasteboard. These are soaked in hot water and applied to the diseased portion of the body and covered over with some water-tight substance and then with cotton. They afterward swell and assume a pulpy consistence. A mustard paper is also manufactured which has a very irritating effect upon the skin. In place of cataplasms a hot-air apparatus and the hot-water coil have been used a good deal of late. This local application of heat is particularly useful in chronic joint diseases, rheumatism, etc.

Antiseptic Wet Dressings.—The application to wounds of wet antiseptic dressings of mull, gauze, lint, linen, etc., in a cold or hot form is even at the present time much used in the treatment of contused, suppurating, and granulating wounds. Wet dressings of one per cent. acetate of aluminium and lead water are used a great deal, and are preferred to dressings containing carbolic acid. The latter is sometimes used too strong by the laity, and also changed too frequently. I have repeatedly seen gangrene of the tips of the fingers caused by carbolic acid applied in this form. A distinct warning should be given against the employment of carbolic and bichloride in wet dressings. They always irritate the skin, and may cause eczema and even gangrene, particularly of the fingers and toes. Gangrene results partly in consequence of the direct chemical action of the carbolic acid upon the tissue elements of the cutis, and partly from the marked transudation into the subcutaneous cellular tissue, causing disturbances of the circulation. The onset of gangrene is masked by the anæsthetic action of the carbolic. Honsell collected from literature forty-three cases of carbolic gangrene, particularly of the fingers and toes; in thirty of the cases the strength of the solution was only one to five per cent. I consider carbolic gangrene rather common, most of the cases not being reported. The sale of carbolic solutions to the laity should be prohibited. What has been said of carbolic gangrene is true of bichloride gangrene, which is, however, rarer. If wet applications of this kind are to be left in place for some time, possibly one or two days, and the effect of moist heat is desired, the applications should be covered with rubber tissue over which cotton is laid, and the whole dressing is then fastened in position by a bandage (hydropathic poultice or Priessnitz's poultice). Wet dressings like these, particularly if made with lead-water, or one per cent. acetate of aluminium, have a powerful stimulating action upon granulations, and the skinning-over process is occasionally very much hastened. If cold is aimed at in the wet applications, for reduction of the heat in any given portion of the body, the dressings will need very frequent renewal.

Cold—Ice.—In such cases it is best to use ice enclosed in rubber bags, or to add ice or snow to the water used for wetting the dressings; or else make a cooling mixture consisting of one part ammonium chloride, three parts of nitre, six parts of vinegar, and twelve to twenty-four parts of water (Schmucker).

The effect of ice and cold applications upon the wound is both analgesic and hæmostatic. Lately, Leiter, of Vienna, has invented an apparatus for obtaining in the most satisfactory manner the effect of cold and heat upon inflamed and injured portions of the body. It consists of a pliable metal tube through which water at any required temperature is allowed to flow. The metal tube can be made to assume any desired form, such as a cap for the head, or a coil for encircling an extremity, or a flat piece for the back, etc. A similar apparatus has been made of rubber tubing, and used as a cold coil for an extremity, an ice cap for the head, or an ice bag for the neck. By allowing hot water to run through the apparatus, heat of any desired intensity may be applied to a part.

Adhesive Plaster.—Small wounds and granulating wounds in the later stages of healing may be covered with adhesive plaster, collodion, ointments, etc. Adhesive plaster is made of some substance like linen, cotton, silk, leather, etc., covered upon one side with a sticky material such as litharge, olive oil, resin, or turpentine, etc.; lead plaster is made with certain resinous substances, with oil, wax, turpentine, etc. The ordinary German adhesive plaster is usually warmed over the flame of a spirit lamp before being applied, and then laid in strips upon the desired portion of skin, which has been previously dried. To prevent the plaster from adhering to the hairs, the latter must be first shaved off with a razor. On sensitive skin ordinary adhesive plaster easily gives rise to eczema. The less irritating emplastrum cerussæ is to be recommended in this particular, although it does not adhere so well.

American Adhesive Plaster.—A very good kind of sticking plaster, though somewhat expensive, is the American adhesive plaster (Ellis's adhesive plaster cloth), in which the sticky material is spread on muslin, linen, or silk.

English Adhesive Plaster.—The English plaster adheres very well and is useful for small wounds; it consists of fine sarcenet having on one side a solution of isinglass and on the other tincture of benzoin (*Emplastrum adhesivum anglicum*). The sticky side should be moistened with some antiseptic solution and not with saliva, and then applied to the skin.

Paris Plaster.—The Paris plaster is more flexible and adheres even better. The recently invented iodoform plaster consists of iodoform,

glycerine, and mucilago gummi arabici, which is made into a solution and spread over linen.

There are many other kinds of adhesive plaster which may be found in the Pharmacopœia. Unna has introduced a very excellent gauze adhesive plaster, made of oxide of zinc or iodoform spread on gauze with some sticky substance, and it is often preferable to the ordinary adhesive plaster. Pick's salicylic soap plaster and Beiersdorf's salicylic-acid soap plaster are both useful.

Collodion.—Of the other adhesive materials I should mention especially collodion, which is a solution of gun cotton in ether and alcohol. By the evaporation of the ether and alcohol the collodion dries in the form of a firm covering which adheres excellently to the skin. It is not suitable for applying to fresh wounds on account of the irritation it causes. Iodoform collodion (1 to 10) is frequently used as a protective dressing, and it is far better than adhesive plaster in that it does not come off by contact with water. A cutaneous wound, after it has been sutured, is frequently painted over with iodoform collodion (Küster, Zweifel, Hans Schmidt), and heals like any wound sutured aseptically, over which there forms a dry aseptic scab. Collodium elasticum (collodion 60, castor oil 2.5, turpentine 7.5) is particularly suited for chapped hands, frost-bites, etc.

Substitutes for Collodion.—Pastes of different kinds may be used as substitutes for collodion. Dermatol, bismuth, airol, and other powders can be mixed with an equal amount of mucilago quinina arabicum and glycerine, to form a good, rapidly drying paste which is used, for example, for sutured aseptic wounds. An excellent covering for a wound may be simply and quickly made by mixing an antiseptic powder with bichloride solution. Schleich uses blood serum in the form of a paste for treating wounds and skin diseases. The preparations are pasta serosa, pulvis serosa (with iodoform and nuclein), pasta serosa cum hydrargyri, etc. Zinc glue (zinc oxide and gelatine, āā 20.0, with glycerine and aq. destill. āā 80.0) acts in the same way as the pastes.

Photoxylin.—Wahl has recommended photoxylin in place of collodion. It is a substance used in photography, and he employs it in a five-per-cent. solution in equal parts of alcohol and ether.

Traumaticin.—Traumaticin, or a solution of gutta-percha in chloroform, is widely employed as an adhesive dressing in place of collodion.

Gummi Laccæ.—Gummi laccæ (Mellez) is also much employed as a substitute for collodion and English adhesive plaster. A solution of the consistence of jelly made by adding alcohol is warmed and spread on cloth, thus forming a cheap and serviceable adhesive plaster which is not attacked by water or fat, etc. Susteck recommends "cutin" as a covering for wounds. It is absorbable and can be sterilised. It is made from the intestine of the ox and is very delicate.

Ointments.—Ointments as dressings for granulating wounds do not enjoy the popularity which they once did, and I rarely use them. For granulating wounds I like wet dressings of one-per-cent. acetate of

ıminium, or antiseptic powders such as bismuth, zinc oxide, iodoım, and dermatol with or without an ointment. There are many ıtments, of which the principal ones are boric-acid ointment, boroıycerin lanolin (Graf), vaseline, salicylic vaseline, carbolised vaseline, lycerine ointment, either pure or mixed with various antiseptics, zinc ıntment, lead ointment, naphthalene ointment, and finally casein ointnent, containing casein, alkalies, glycerine, vaseline, water, and an ıntiseptic adjuvant (one half per cent. zinc oxide and one half per cent. carbolic acid). If applied with water the latter ointment dries quickly and forms a very smooth, thin covering. An excellent base for making ointments is lanolin, recommended by Liebreich, in which bacteria cannot grow. Glycerine fats, on the other hand, become easily rancid under the influence of light, and then become a good medium for the growth of micro-organisms (Fränkel, Gottstein).

Kirsten recommends mollin as an adjuvant to gray mercurial and iodine ointments.

CHAPTER III.

GENERAL RULES FOR THE APPLICATION OF BANDAGES AND RETENTION APPLIANCES.

The different kinds of bandages.—The application of the ordinary roller bandage.—The "reverse."—The removal of bandages.—The rolling of bandages.—The application of bandages to particular parts of the body (head, neck, trunk, upper and lower extremities).—The application of handkerchief bandages to different portions of the body.

§ 50. **Application of Bandages.**—The ordinary bandages are made of linen, flannel, muslin, webbing, or gauze, etc. For bandaging wounds, as we have said before, we preferably employ sterilised mull or starched gauze. The latter are first soaked in a 1 to 1,000 solution of bichloride or a three-per-cent. carbolic solution, squeezed dry, and then applied in a damp condition to the selected portion of the body, thus making a well-fitting and strong permanent dressing, as illustrated in Figs. 143 and 144, on page 175.

The rubber bandage (made from ordinary caoutchouc) or the bandage of elastic webbing is used when it is desired to apply a dressing to exert pressure. Elastic bandages are adapted for application about the thorax, the abdomen, etc., where other bandages become easily displaced and loosened. There are both single and double roller bandages, the latter being illustrated in Fig. 149. Triple and quadruple rollers were formerly much in vogue, and can be easily made by fastening together a couple of ordinary bandages. The many-tailed bandage, as it is called, consists of several strips of bandage overlapping laterally and joined in the centre by a single cross strip.

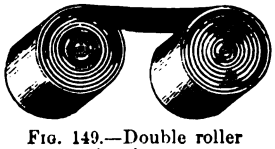


Fig. 149.—Double roller bandage.

Application of the Roller Bandage.—The ordinary roller bandage is applied by holding the end of the bandage upon the desired spot with the index finger or thumb of the left hand, while the roller is directed upward (Fig. 150). The first turn of the bandage is secured by a second, making two thicknesses of the bandage at one place; then

the bandage is unrolled spirally upwards about the part, making each upper turn overlap about half of the width of the one next below. I usually apply the bandage from left to right. If it is desired to rapidly secure a dressing in place, each spiral turn may be separated by a considerable distance from the next lower turn (Fig. 151), and subsequently the bandage may be completed in the regular way. If one attempts to apply a linen or gauze bandage, for example, to the upper or lower extremity, with circular or spiral turns, it will soon be noticed that the lower edge of each turn does not fit tightly to the extremity, and that its "set," particularly in the case of the forearm and leg, is uneven. For preventing this looseness of the lower margin of each turn, and to make the whole bandage fit evenly and firmly, it is customary to make what is called a "reverse," which is best done as follows (Fig. 152): 1. The roller is grasped by the right hand in such a way that one looks into the palm of the hand, the dorsal surface is directed downwards, and the bandage drawn tight and smooth obliquely upwards, while its lower edge is held firm by the left thumb (Fig. 152, *a*). 2. The traction on the obliquely directed portion of the bandage beyond the left thumb is then relaxed (Fig. 152, *b*). 3. The upper edge of the bandage is then folded over

Fig. 150.—Application of the ordinary roller bandage.

Fig. 151.—Spiral bandage.

Fig. 152.—Application of the reverse bandage.

downwards (Fig. 152, *c*). The points of reverse should, as far as possible, be made at the same part of the circumference of the extremity, and lie one above the other. This method should be employed not only in bandaging an extremity, but any other portion of the body, so

as to make the turns of the bandage fit into the inequalities of the particular locality. The bandage is usually completed by one or two circular turns. While making the reverses care should be taken that ridges and folds are not allowed to form. Considerable practice is necessary in order to be able to put one on quickly and accurately. The end of the bandage should be fastened in place with a safety-pin, or it may be slit up at the end with scissors, or simply torn lengthwise in the middle, if it is a muslin or gauze bandage, and the split ends carried around the extremity in opposite directions and knotted together.

A bandage is taken off by unwinding the turns in the reverse direction to which they were put on—i. e., the turn last applied is the first

Fig. 153.—Rolling a bandage.

Fig. 154.—Fascia nodosa.

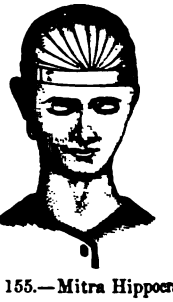


Fig. 155.—Mitra Hippocratis.

to be taken off. At the same time the bandage is rolled up, and during the unwinding is quickly passed from one hand into the other. The removal of a mull or gauze bandage is generally accomplished by simply slitting it up with bandage scissors.

In Fig. 153 is illustrated the method of rolling a bandage. Mull and gauze bandage rolls are best and most rapidly made by means of a small rolling machine.

Application of a Bandage to the Head.—The method of applying bandages to the head is illustrated in Figs. 154–157.

Fig. 154 represents the fascia nodosa or knotted bandage. The middle of a strip of bandage is laid, for example, on the left temple, and one end of the strip is carried over the crown, the other under the chin to the right temple, and at this point the two ends are crossed, the one which came from under the chin passing around the forehead, the other around the occipital region, and the two ends are then knotted together. The principle of this knotted bandage can be used with some variations for almost any desired portion of the body. Its chief use is for exerting pressure on some particular spot, which can be

creased by inserting beneath the bandage a pad of cotton or gauze, &c. It is also used in the inguinal region (Fig. 183), as a temporary substitute for a hernia truss.

Mitra Hippocratis.—The mitra Hippocratis (Fig. 155) is made with a double roller, or, what is simpler, with an ordinary roller bandage. When the double roller is employed its centre is applied in the middle of the forehead, one roller being carried horizontally around the head towards the right, the other towards the left, and at the occiput the two rollers are crossed in the manner of the fascia nodosa; then an assistant carries one roller over the crown to the forehead, while the operator, with the second roller, takes a circular turn horizontally around the head and crosses the roller, which has been carried over the crown, upon the forehead. This is continued, one roller being carried from the forehead to the occiput and then back again to the forehead, first on the right side and then on the left of the original median strip carried sagittally over the crown, each circular turn of the other roller securing the strips passing over the crown. The entire skull is thus covered with strips of bandage running forward and back in a sagittal direction. Finally, the ends of both rollers are carried circularly around the head and fastened in place with a safety-pin. The mitra Hippocratis is only occasionally applied with a double roller, but it is well to understand the principle of it in bandaging wounds of the head (see page 175, Fig. 143). A mull or wet gauze bandage may be applied to the head partly with circular turns and partly with turns passing back and forth in a sagittal direction over the top of the head.

Capistrum Duplex.—The capistrum duplex is not very often used now, but it was at one time in great repute for treating fractures of the lower jaw, as was also the capistrum simplex. The funda maxillæ (Fig. 174) has the same effect as the capistrum simplex and duplex, and is, furthermore, much better and simpler. Some of the turns made in the capistrum duplex are used for applying bandages in wounds of the head and neck, and hence it should be spoken of here. The description of the old-fashioned capistrum simplex will be omitted. The capistrum duplex is begun with the end of the roller on the vertex, then it passes down in front of the left ear, under the chin, and up in front of the right ear to the vertex again; then from this point it passes around the occiput to the right side of the neck, under the chin, and up in front of the left ear, covering the first turn in great part, back to the vertex again; then around the occiput to the left side of the neck, beneath the chin, and up in front of the right ear to the

Fig. 156.
Capistrum duplex.

vertex. In this way three turns of the bandage are made in front of each ear, and then it is carried from the neck in front of the chin and the lower part of the under lip, and is finally terminated by a circular turn around the forehead and occiput. The circular turn around the front of the chin can be made between the second and third turns taken in front of the ear. In applying it over an antiseptic dressing the neck should also be included in the bandage.

Fig. 157. Monoculus.

Monoculus and Binoculus.—Fig. 157 represents the method of applying the monoculus, which begins with a circular turn about the head, starting from the temporal region. The rest can be understood from Fig. 157. The so-called binoculus, or bandage over both eyes, is performed by first covering one eye with a circular turn of the bandage and then carrying the bandage with obliquely descending turns over the other eye.

Application of a Bandage to Neck and Thorax.—The application of bandages to the neck is accomplished by making circular turns, to which, in the case of large wounds, are added cross turns under the axilla and over the shoulder (see page 175, Fig. 144). Bandages are applied to the thorax by circular turns, with or without reverses. To keep the bandage from becoming displaced, every other turn can be carried from the back over the shoulder and secured with safety-pins at the points of meeting with the horizontal turns; or the circular turns may be made to ascend from below upwards on the thorax, and finished by oblique turns about the shoulder and axilla like a spica humeri (Figs. 163 and 164). For bandaging a wound, after applying a thick cushion of dressings, we employ starch bandages, which, after drying, fit closely and do not become easily displaced. Elastic bandages are also to be recommended for the trunk, as they retain their position very well.

Bandages for the Breast. *Suspensorium Mammæ Simplex* (Fig. 158).—The bandage for the right breast is begun by a circular turn about the lowermost portion of the thorax. The bandage is then carried obliquely so as to envelop the lower part of the gland, over the opposite shoulder, then across the axilla, over the shoulder and across the back, again to the right breast at its upper part, and then once more over the shoulder, etc. The upper and lower portion of the gland is crossed alternately, and then its middle part, and finally the bandaging is completed by a circular turn around the lowermost portion of the thorax covering the preliminary turns (Fig. 158). The suspensorium mammæ duplex and a light supporting bandage for both breasts can

e applied very simply by using the method illustrated in Fig. 158 on oth sides.

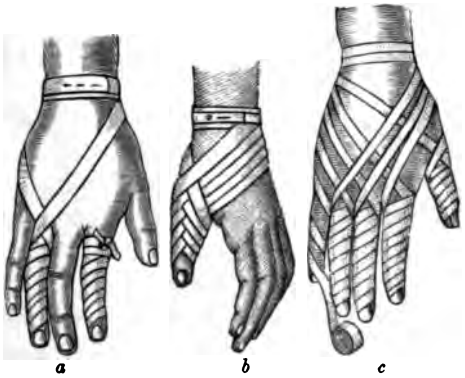
Antiseptic Retention Dressing after Amputation of the Breast and cleaning out the Axilla.—After amputation of the breast, accompanied by cleaning the carcinomatous lymphatic glands out of the axilla, I first put on a dressing of several layers of sterilised gauze placed in direct contact with the wound, then over this I apply absorb-

Fig. 158.—Suspensorium mammæ duplex and small outer bandage for the mamma.

Fig. 159.—Aseptic dressing for use after an amputatio mammæ with cleaning out of the left axilla.

ent cotton, covering in the shoulders and entire thorax. These materials are then bound on by a sterilised mull bandage encompassing the thorax, neck, and shoulders, the edges of the dressings, particularly in the axilla, neck, and at the lower border of the breast, being very carefully filled in with absorbent cotton; then the arm on the side which has been operated upon is placed in contact with the thorax and also covered with sterilised absorbent cotton. After this the arm is immobilised by a sterilised mull and finally a gauze bandage encircling the thorax, neck, and shoulder (Fig. 159).

Application of Bandages to the Upper Extremity. — The methods of applying bandages to the fingers are illustrated in Fig. 160, *a*, *b*, *c*. They are begun with a circular turn around the wrist, and then carried across the dorsum of the hand to any particular finger, and, after encircling it, brought back again to the back of the wrist (Fig. 160, *a*). A finger can be bandaged, as

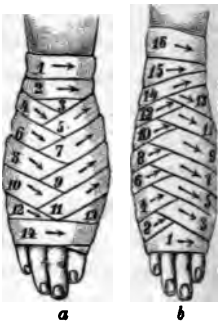


a *b* *c*

Fig. 160.—Application of bandages to the fingers.

illustrated for the little finger in Fig. 160, *c*, by making oblique spiral turns down to its tip, and then covering in the finger by oblique or circular turns from tip to base. The finger bandage can also be carried in the reverse direction, beginning on the finger and terminating at the wrist. Moreover, the thumb may be bandaged in the way pictured in Fig. 160, *b*; beginning with a circular turn around the wrist, the bandage is carried to the tip of the thumb, and around this, over the back of the hand, and so on, with oblique turns till the base of the thumb is reached. If it is desired to bandage the tip of the finger, the roller is carried along the back or palmar surface of the finger over its tip and back on the other side opposite the starting-point, where it is retained while a circular turn is made around the base of the finger, over the ends of the loop, securing it in its position. A bandage is applied to the whole hand according to the rules for the spica manus (Fig. 161). The bandage is started at the wrist by a circular turn, and then oblique or figure-of-eight turns are taken by the roller, gradually proceeding downwards till the finger ends are reached. It is concluded with a circular turn about the wrist.

Fig. 161.—Spica manus.



a *b*

Fig. 162.—Bandage for the hand.

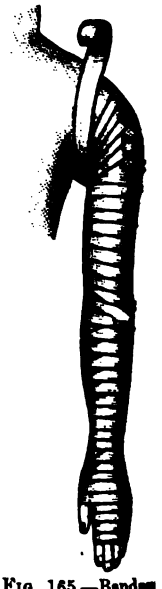


Fig. 165.—Bandage for the entire upper extremity.

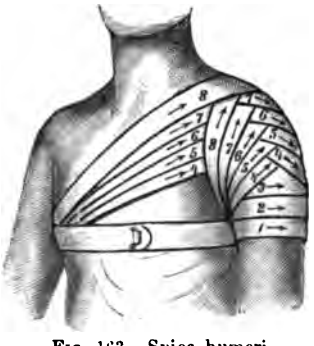


Fig. 163.—Spica humeri ascendens.

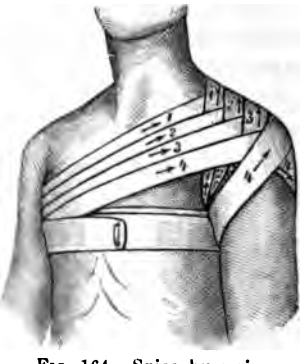


Fig. 164.—Spica humeri descendens.

Another way of bandaging the hand is represented in Fig. 162,

and *b*. It is begun with a circular turn around the wrist (Fig. 162, *a*) or around the ends of the fingers, and proceeds up or down with figure-of-eight or oblique turns, half of the width of each upper turn overlapping a corresponding amount of the next lower turn, and finally terminating with a circular turn around the finger tips or the wrist. If it is desired to include the finger tips, as, for instance, in an antiseptic protective dressing, the end of the bandage is secured while the roller is carried over and around the ends of the fingers and back on the opposite side in the form of a loop, and the extremities of the loop are then fastened in place by a circular turn.

Application of a Bandage to the Shoulder.—The shoulder is bandaged by using the spica humeri ascendens (Fig. 163) or descendens (Fig. 164). The spica humeri ascendens (Fig. 163) begins with a circular turn around the upper end of the arm, the bandage being then carried over the lower end of the shoulder from within outwards, then over the back to the opposite axilla and back again across the breast over the shoulder through the axilla, and finally terminated by a circular turn around the thorax. The spica humeri descendens (Fig. 164) is applied in the reverse direction—i. e., it is begun with a couple of circular turns about the thorax, and finished with descending oblique or cross turns over the shoulder, terminating on the arm lower down, or with a circular turn about the thorax again. Fig. 165 represents the method of applying a bandage to envelop the whole arm. The turns of the spica humeri around the thorax are omitted in the illustration in order to economise space, but the rest of the figure illustrates the bandage for the entire upper extremity.

Application of Bandages to the Lower Extremity.—The bandage for the lower extremity is begun by enclosing the foot (Fig. 166, *a* and *b*) by a circular turn made back of the toes, as illustrated in Fig. 166, *a*; then two or three slightly oblique turns are taken, with or without the reverse (Fig. 152), and at about the fourth turn of the bandage the latter is carried obliquely over the anterior aspect of the ankle-joint toward the internal malleolus, and from here over the heel and around the outer malleolus again to the inner side of the foot; thence across the sole, making two or three stirrup turns, and then ascending the leg with circular turns, followed by oblique turns and the reverse (Fig.

Fig. 166.—Application of bandages to the foot.

152). If the heel is to be included (Fig. 166, *b*), the bandage is begun as in Fig. 166, *a*; but after taking two or three turns, it is carried across the dorsum of the foot to the heel, around the latter, over the dorsum to the inner side of the foot, thence across the sole to the outer side of the foot, again over the dorsum to the heel, each preceding turn being covered by half the width of the following turn, and so on till above the ankle, when two circular turns are made, and then these are succeeded by oblique turns with reverses ascending the leg.

For applying a bandage to the region of the knee-joint the testudo inversa (Fig. 167, *a* and *b*) or reversa (Fig. 168, *a* and *b*) is used. In the testudo inversa (Fig. 167), after several circular turns are made around the leg, an oblique turn is carried across the popliteal space toward the thigh, passing around the latter back across the popliteal space to the leg and so on gradually covering in first the lower, then

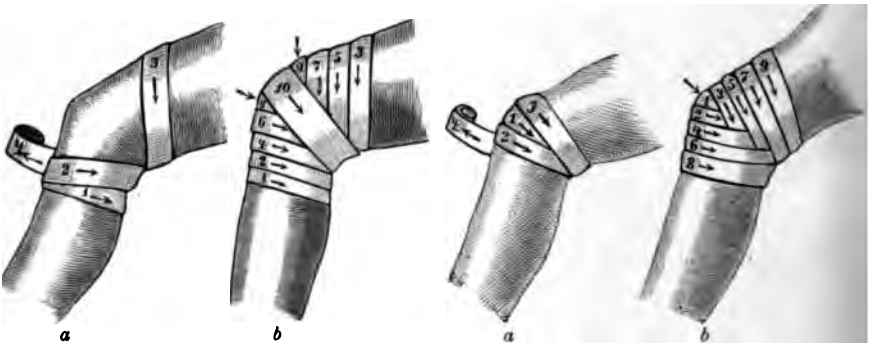


Fig. 167.—Testudo inversa genus. Fig. 168.—Testudo reversa genus.

the upper part of the anterior aspect of the knee, the last turn crossing the centre of the anterior aspect of the knee transversely (Fig. 167, *b*). The testudo reversa is begun with a circular turn around the middle of the knee, and the remaining turns are made obliquely, first above and then below the original circular turn.

The testudo bandage is also employed for the elbow.

When it is desired to include the entire lower extremity in a bandage, the region of the knee may be covered simply by circular turns (Fig. 171). The hip, in the same way as the shoulder, may be bandaged by a spica coxæ ascendens (Fig. 169) or descendens (Fig. 170). The spica coxæ ascendens is begun with a circular turn around the upper part of the thigh, and then, in the case of the left hip, the bandage is carried across the gluteal and sacral region towards the opposite anterior superior spine of the ilium, thence over the lower part of the abdomen and inguinal region back to the thigh. For the right thigh,

the bandage is carried over the groin and abdomen to the anterior superior spine, thence across the sacral and gluteal regions back to the thigh. Each succeeding turn ascends a little higher on the thigh, and the bandage is finally completed by a circular turn around the abdomen. The spica coxæ

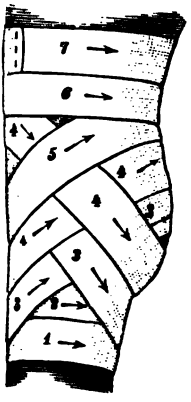


Fig. 169.—Spica coxæ ascendens.

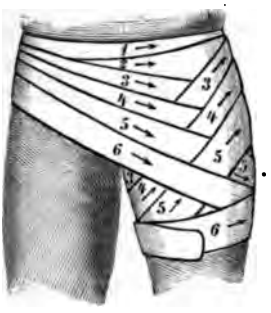


Fig. 170.—Spica coxæ descendens.

Fig. 171.—Bandage for the entire lower extremity.

descendens (Fig. 170) is begun where the ascendens terminates, by circular turns around the abdomen, and is made to descend by oblique turns in a manner the reverse of the spica ascendens, and finally to come down the thigh by circular and oblique turns made with reverses. The method of bandaging the entire lower extremity will be understood from the previous remarks (Fig. 171).

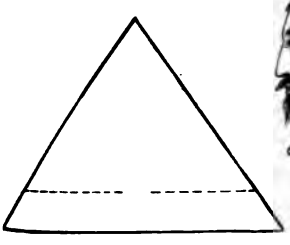


Fig. 172.—Double piece of cloth; bandage to support the jaw.

Fig. 173.—Handkerchief or impromptu cloth bandage for the jaw.

Fig. 174. Funda maxillæ.

§ 51. **Application of Handkerchief Bandages.**—Properly shaped pieces of cloth as substitutes for bandages are not suitable for dressing wounds antiseptically, but under other circumstances—viz., for applying a light

protective dressing, or for the after-treatment of a wound, or in an emergency—they do very well, and possess the advantage that the material for making them can always be obtained in every household. These bandage substitutes are made of triangular or quadrilateral-shaped pieces of cloth. One of the most useful of these bandage substitutes is the sling bandage. The base or longest of the three sides of a triangular piece of cloth is cut in the manner indicated by the dotted lines in Fig. 172, thus making a five-tailed piece of cloth, which is excellent as a bandage for the inferior maxilla (Fig. 174). Another very good bandage substitute may be made by splitting the smaller sides of a long rectangular piece of cloth and applying it as a bandage for the head in the manner indicated in Fig. 173, *a* and *b*.

These pieces of cloth used as bandage substitutes may either be folded up in the shape of a cravat and made to encircle any part of the body, or they may be used as simple unfolded pieces of cloth. The folded strips are applied like any ordinary roller bandage. For the sake of brevity I shall confine myself to the following short description of the different methods of using these substitutes for roller bandages.

As regards the head, a triangular piece of cloth folded into the shape of a cravat is an excellent substitute for the monoculus in bandaging the eye, and for making a horizontal bandage on the forehead like the fascia nodosa (Fig. 154). A very useful bandage as a temporary dressing for a fracture of the upper or lower jaw is the funda maxillæ (Fig. 174), which is made from the five-tailed sling bandage represented in Fig. 172. The three-cornered piece is folded up like a cravat, the middle of which is placed under the chin of the patient, and the two ends are knotted together upon the top of the head. The point of meeting of the other two tails is held in front of the chin, and the ends of these tails carried around the back of the neck, where they are crossed and brought forward and knotted together on the forehead. Mention should also be made of the capitium parvum, magnum, and quadrangulare.

Fig. 175.—Capitium parvum.

Fig. 176.—Large handkerchief bandage for the head.

The Small Head-dress (*Capitium parvum*, Fig. 175).—An ordinary triangular piece of cloth is laid over the head, with the centre of its longest side at the root of the nose, and its apex or angle opposite the longest side hanging down the neck. The lateral tails of the tri-

ıgle are carried around the neck back to the forehead, where they are ed together. The tail hanging down the neck is turned back over he top of the head nd secured with a afety-pin.

The Large Head-dress (*Capitium magnum*, Fig. 176). – The triangular sling bandage is cut in the manner represented in Fig. 172 and laid on the scalp, with the centre of its longest side at the root of the nose. The two anterior tails hanging down on each side of the face are passed around the neck, as in the capitium parvum, and brought forward and knotted together on the forehead. The other two tails are tied under the chin, and the apex of the triangular piece of cloth is finally brought forward, as in the capitium parvum, from beneath the tails, crossed behind the neck, and secured in front by a safety-pin.

a *b*

Fig. 177.—Capitium quadrangulare.

The Four-tailed Head-dress (*Capitium quadrangulare*, Fig. 177, *a*). —A quadrilateral piece of cloth is so folded over the top of the head that its under border overlaps the upper by about a handbreadth (Fig. 177, *a*). The two upper—or, rather, posterior—angles are knotted together under the chin, while the other two corners are drawn somewhat forward and upwards. Then the projecting lower edge of the ıder portion of the cloth is turned up and back, and the two anterior

Fig. 178.—Handkerchief bandage for the breast.

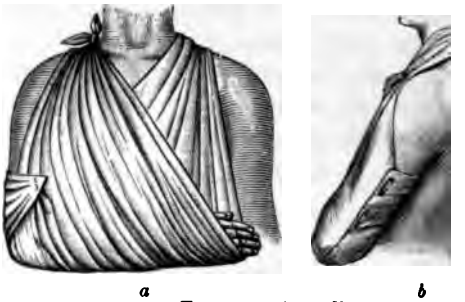
Fig. 179.—Handkerchief bandage for the breast.

corners are carried around behind the neck and tied, thus formir bandage represented in Fig. 177, *b*.

An ordinary three-cornered piece of cloth can be applied t thorax in the manner illustrated in Fig. 178. The longest side o triangle is placed around the lower portion of the thorax, while apex or opposite angle of the triangle is carried over either the r or left shoulder and tied to the other two tails or angles of the tris behind.

In suitable cases a bandage may be applied as in Fig. 179—i. folded piece of cloth is placed around the thorax and prevented : becoming displaced by a couple of retention straps carried ove shoulders and having their junctions with the breast-piece secure safety-pins. The female breast can be supported by an ordinar angular piece of cloth, or one made double, as shown in Fig. 172.

Fig. 180.—Handkerchief bandage for supporting the mamma.



a *b*

Fig. 181.—Arm-sling.

sling is applied with the centre of the base of the triangle beneat breast which it is desired to support. Then the lower tails or co at each side of this point are carried around the thorax, while the three tails are conducted across the axilla and over both shoulde the back, where they are tied together.

The triangular piece of cloth is very frequently used for m the so-called mitella, or sling (Fig. 181). The following is the m of applying the mitella: The three-cornered piece of cloth is gr at each extremity of one of the shorter sides and placed betwee thorax and the arm bent at right angles, with one angle of the tri lar cloth projecting around back of the elbow. The upper end c longest side is then carried over the opposite shoulder and tied t other end of the longest side behind the neck. The third corn angle of the triangular cloth is carried around the back of the to the front and secured in this place by a safety-pin (Fig. 181, *a*) stead of bringing this third angle around in front of the elbow,

be turned in, and then the two edges of the sling can be pinned behind the arm, as represented in Fig. 181, *b*. Moreover, it is a very good

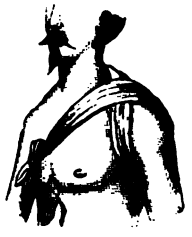


Fig. 182.—Handkerchief bandage for the shoulder or axilla.

Fig. 183.—Knotted bandage about the inguinal region.

Fig. 184.—Handkerchief bandage about the inguinal region.

plan not to tie the ends of the sling around the neck, as the knot causes discomfort, but to bring the extremities to the front again, and either sew or pin them in that position.

A four-tailed or four-cornered piece of cloth can be used for a sling, like the mitella, but the manner of its application is more complicated, without being any better.

Strips of bandage can be used instead of the mitella. They are fastened to the coat or tied at the back of the neck. Slings can also be made of stout black ribbon, which encircle the arm and pass around the neck. The arm may also be supported by inserting the hand in the waistcoat or partially buttoned coat.

Fig. 185.—Handkerchief bandage for the hand.

Fig. 186.—Handkerchief bandage for the foot.

Fig. 187.—Handkerchief bandage for the hand.

Fig. 188.—Handkerchief bandage for the foot.

In Figs. 182 to 186 are represented the methods for applying pieces of folded cloth around the axilla or the shoulder, about the inguinal region, the hand, and foot, and they need no further explana-

tion. In Fig. 183 the principle of the fascia nodosa (Fig. 154) is used —i. e., the ends of the bandage are twisted about each other for exerting pressure upon some particular spot. By means of a pad of cotton, lead, rubber, or other material, the pressure can be increased.

In Figs. 185 and 186 are represented the methods of applying a bandage substitute to the hand and foot. The hand is wrapped in a three-cornered piece of cloth in the following manner (Fig. 187): The centre of the base of the triangle is placed at the wrist, while the angle opposite the base projects a little beyond the tips of the fingers. This projecting angle is then turned back over the fingers and dorsum of the hand to the wrist, the lateral angles are given a turn around the wrist and made to cross each other on the dorsum of the hand, then brought back to the wrist and tied. The same method is carried out on the foot, but instead of knotting the ends around the leg, they can be carried back from the leg and crossed over the dorsum of the foot, and finally tied after making a circular turn around the foot (Fig. 188).

CHAPTER IV.

THE SICK-BED OF THE PATIENT.—IMMOBILISATION APPLIANCES AND DRESSINGS.

The sick-bed of the patient.—The bed.—Adjustable beds.—Bed fittings: Air-cushions; water-cushions.—Supports.—Wire cradles.—Appliances for lifting patients.—Appliances for the sick-bed: Cushions; straw splints.—Single and double inclined plane.—Petit's leg splint.—Suspension.—Wire gutters and baskets.—Splints.—Materials for making splints (wood splints, paste splints, metal splints, glass splints, plaster splints, extension splints, articulated splints).—Complicated appliances for the sick-bed.

§ 52. **The Sick-bed of the Patient.**—The greatest care must be exercised as regards the sick-bed of the surgical patient. The bed should be so arranged that the injured portion is easily accessible to the physician. In general, it is best to place the head of the bed towards the window, to prevent the patient from being blinded by the light. It should be as elastic as possible, and a spring or horse-hair mattress is far preferable to a feather bed. If the patient must be confined to bed for a long time, it is a very good plan to have a bedstead with contrivances for changing its shape, so that he can readily be brought from the horizontal into a sitting position. A bedstead which the patient can adjust to suit himself with very little effort is particularly good. For raising and moving a bed without disturbing the patient special apparatus have been devised by Allzeit and others. A water-tight rubber protective should be placed over the mattress to prevent it from getting wet. "Christia," a comparatively cheap, durable, and sterilisable preparation, has been recommended by Evens and Pistor, of Cassel, as a substitute for the ordinary water-tight substances hitherto used (rubber, oiled silk, gutta-percha, muslin, etc.). The greatest care must be used to keep the bed-linen perfectly clean, so that the dressings shall remain antiseptic. If the patient must lie for a long time upon his back, the sacral region particularly should be protected from all injurious pressure by means of elastic cushions. For this purpose we use ring-shaped air-cushions, or, what is still better, large water-cushions filled with warm water.

A swinging crane may be placed over the head of the bed sling attached to the foot of the bed, so as to enable the patient to himself. By means of hoops joined together, or cradles (Fig. the bed-clothes can be elevated the diseased portion of the body which their pressure may be ur fortable, or sometimes even pain

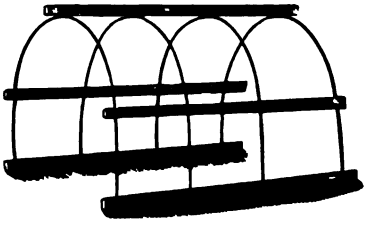


Fig. 189.—Wire cradle for the limbs.

For lifting the patient or some tion of his body with as little dis ance as possible, we make use, necessary, of special appliances lifts. In the majority of inst they are not needed for changing the dressings or bed-clothes, enabling the patient to empty his bowels, and a nurse can rend the assistance required; but under many conditions—for example, the dressings on a compound fracture have to be renewed, and the must be held lifted up from the bedding for some time while being done—we employ windlasses, pulleys, belts, fenestrated scat etc. The portable fenestrated bed-lift, which permits of extensio of defecation in the recumbent position, invented by Hamilton Volkmann (Fig. 190), and Hase's apparatus (Illustr. Monatschr ärzt. Polytech., Heft 6, 1883), are very useful contrivances. mann's bed-lift is placed on the bed over the mattress and can be by two attendants, while the supports at each extremity can be automatically adjusted so that the apparatus can be retained at any desired elevation. For elevating any single portion of the body, such as an extremity, the ordinary suspension apparatus will be found sufficient (Fig. 194). For enabling the patient to raise the upper portion of his cranes can be devised with two ropes and rings for him to gr straps can be attached to the ceiling or to the foot of the bed. pelvis of the patient may be lifted by a trestle on which is stret broad leather belt provided with a fenestrum for permitting e

Fig. 190.—Elevated frame for fractures of the verteb pelvis (Hamilton, Volkmann).

f the bowels. But if it is impracticable to disturb the position e patient at all, an opening can be provided in the mattress and n of the bed for enabling him to empty his bowels, or an arrange- can be made by which the mattress may be drawn from under The adjustable bed of Hamilton and Volkmann is exceedingly adapted for this purpose.

53. **Sick-bed Appliances—Splints, Cushions, etc.**—There are numer- apparatus and contrivances for obtaining the necessary and secure ion of a patient who is confined to bed, or of the particular part e patient which has been operated upon.

. **Cushions.**—The most useful cushions for retaining a diseased part y required secure position are made of chaff, chopped straw, saw- or sand. The cushions should be only partially filled, so that the nts may be shifted and the cushion given any desired shape for g the injured extremity and holding curely. Sand-bags or cushions are lent on account of their weight, and ng, sausage-shaped bags are the best, ey can be placed along the whole h of each side of an extremity, espe- the leg. Chaff cushions are also good, as their contents can be collected at each end of the bag, h may then be wrapped around an extremity and secured by a age, cloth, etc. The same effect was obtained by the old-fashioned splint (Fig. 191), which can be made very simply by wrapping wo ends of a good-sized strip of cloth around bundles of straw or similar material; the extremity is placed between two bundles, e it can be secured with a bandage. Tightly stuffed cushions orse-hair or seaweed, the shape of which cannot be altered, are used.

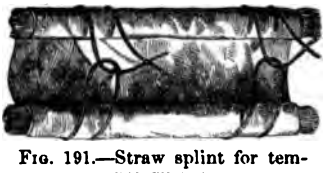


Fig. 191.—Straw splint for temporary use.

. **The Single and Double Inclined Plane.**—If it is desirable to ate the peripheral end of an extremity either for inflammatory swelling, simple congestion, or for some injury or after an operation, it can be accomplished very readily by placing beneath the extremity chaff cushions arranged so as to form a simple ied plane. The same result can be obtained by placing under the n ordinary board with its distal end raised, or by using Petit's

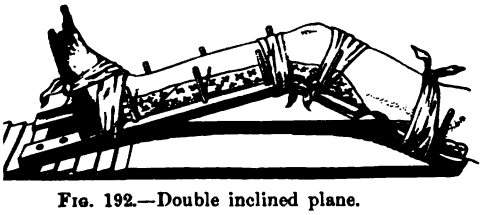


Fig. 192.—Double inclined plane.

box splint (Fig. 193), or suspension. The double inclined used chiefly for the lower extremity. A large, wedge-shaped will answer the pur a couple of board by a hinge and with strings so as t tain any desired ang march's double plane, fitted with la tention pegs, is exce useful (Fig. 192).

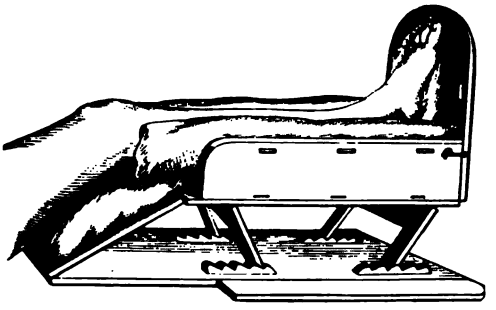


Fig. 193.—Petit's box splint for the leg.

3. **Box Splints** w a good deal at one t fractures of the other injuries below the knee. Petit's box splint (Fig. 193) i good one. All the other box splints have been replaced by splints, particularly those of plaster of Paris.

4. **Suspension.**—The old-fashioned suspension appliances f ing the extremity in proper position are at present entirely s ous, as we now combine all the various retention and extension dressings with suspension. We shall return to this subject later in the description of the various splints.

Suspension in curvature of the spine, etc., will be described in the text-book on Regional Surgery. Rauchfuss's suspension appliance is represented in Fig. 218.

The simplest way of suspending an extremity is to use a framework having two upright rods of wood with a horizontal cross-piece. For children, simple wooden hoops are fastened to the bed, and to these the extremity is secured by a bandage or strips of adhesive plaster. I use an adjustable iron frame with rollers (Fig. 194). The cross-bar raised or lowered to any convenient height by means of the han

Fig. 194.—The author's suspension a

The rope for exerting the traction with the weight (*G*) runs over wheels which can be moved to one side or the other and readily retained at any point by the notches in the cross-bar. Iron frames which can be fastened to the bed are very useful.

5. **Wire Splints.** *Wire Gutters, Stockings, and Cases.*—Wire gutter splints (Figs. 196, 197) are as simple as they are comfortable, and have supplanted to a large extent the contrivances just described. Wire gutters are usually made of wide-meshed wire gauze, padded with a thin layer of horse-hair or small cushions of cotton, jute, etc. They are straight, or bent at an angle, and of various lengths and sizes. As they are flexible they can be made to fit the limb more or less accurately by means of straps. Roser's contrivance is very useful. It con-

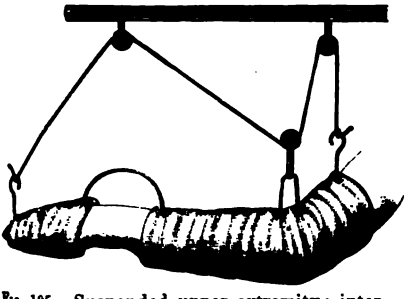


Fig. 195.—Suspended upper extremity; interrupted plaster dressing with splints and telegraph wire.

Fig. 196.—Wire gutter for the upper extremity.

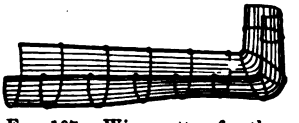


Fig. 197.—Wire gutter for the lower extremity.

sists of a wire gutter for the entire lower extremity, and is made in two or three different parts, which can be telescoped together to any desired extent and fixed in the proper position with strings. For immobilising both lower extremities, together with the pelvis—for example, in fractures of the latter, Bonnet's wire stockings were once used. Bonnet has also invented an excellent wire frame or case for inclosing the whole body in fractures of the vertebræ.

6. **Splints and Splint Bandages.**—Splints are generally employed in the treatment of fractures and in making dressings which harden after their application, as well as ordinary antiseptic dressings.

Splints are made in an immense variety of shapes, either resembling more or less deep gutters, or only slightly concave or entirely flat; they may be straight, or bent at a right, acute, or obtuse angle. Splints are made of wood, papier-maché, metal, silica, felt, plaster, etc.

Wooden Splints.—The stiff, unyielding wooden splints are usually made from the coarse heart wood of the tree; they are flat or slightly concave, or fashioned to fit the contour of a particular portion of the body, and they may be straight or bent at an angle. Fenestræ are

usually cut in them to correspond to any projecting portions of the body, such as the internal condyle of the humerus at the elbow, or the malleoli at the ankle, and thus the skin over these points is preserved from an undue amount of pressure, which might cause it to become gangrenous. In Fig. 198 are represented various kinds of splints for

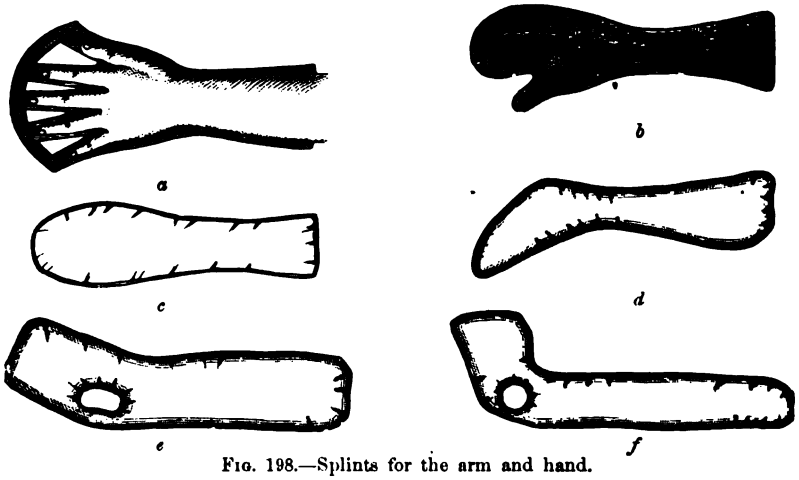


Fig. 198.—Splints for the arm and hand.

the upper extremity; they are straight, or bent at an acute or obtuse angle, and made of wood or papier-maché. The splints (*c* to *f*) are padded with cotton, jute, or tow, and then covered with rubber tissue, the ends of which are stuck to the back of the splint with chloroform. These splints are used almost exclusively for inflammation, injuries, and fractures of the fingers, hand, and forearm. The splint *d* is somewhat modified from Nélaton's pistol splint for fracture of the radius.

Wooden arm splints for the entire upper extremity can be made like the models represented in Fig. 198, *e* or *f*. Esmarch's arm splints

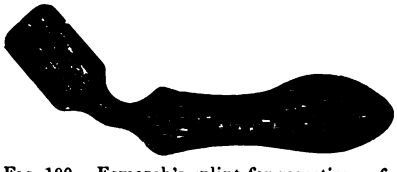


Fig. 199.—Esmarch's splint for resections of the elbow.

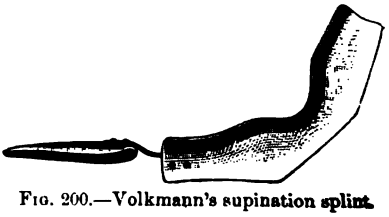


Fig. 200.—Volkmann's supination splint.

(Fig. 199) are also very useful—for example, after resection of the elbow-joint; Volkmann's supination splint is likewise good, and enables the arm to be immobilised in a position between pronation and supination (Fig. 200).

arch's double splint (Fig. 201) is exceedingly good for a resected ›int. It consists of two parts upon which the arm rests, the ortion being joined lower by a steel g. 201, *b*). If it is e to place the fore- l hand in a verti- ition, in cases of ıflammation, in or- lessen the conges- olkmann's suspen- int is very useful 2); the ring at the ty of the splint is ɛd for suspending : vertical position; arrangement of s and bandages will ly be found suffi- r securing the fore- position.

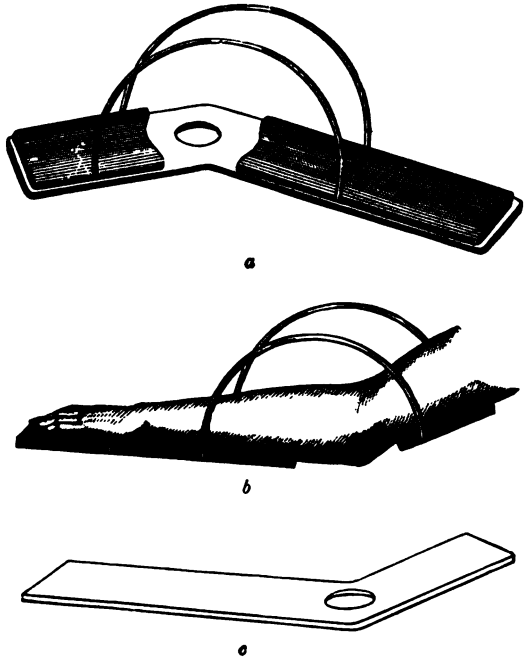
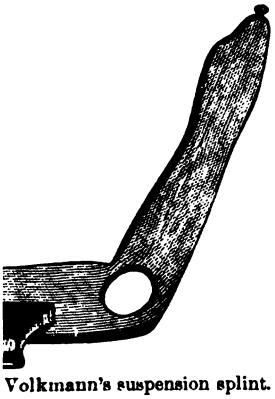


Fig. 201.—Esmarch's double splint for resections of the elbow.

two excellent of Esmarch and 'or resection of the ıre represented in)3, *a*, *b*, and Fig. 204. Esmarch's bow splint is easily made piece of wood or sheet iron. The wooden splints for the lower extremity have been mostly supplanted by metallic splints. Fig. 205 shows Volkmann's wooden dorsal splint, and Fig. 206 Esmarch's wooden splint for a resected ankle. It is applied to the posterior surface of the leg, which is then encased in plaster of Paris and suspended by telegraph wire.


Volkmann's suspension splint.

Pliable Wooden Splints.—In addition to these stiff wooden splints there have been recommended splints made of wood which is capable of bending, but they have not been received with ı favour as they deserve. They are always well suited for an impromptu dressing, especially in transporting patients to

the hospital. Even in ancient times, according to the assertion E. Fischer, splints were manufactured from wood which could bent into any desired shape. F this purpose there were used t stem of the Spanish broom, stri of wood cut very thin, pieces veneering, green twigs, palmet

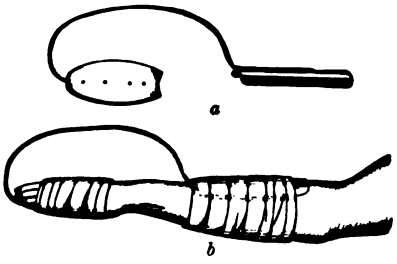


Fig. 203.—Esmarch's interrupted splint for resections of the wrist.

Fig. 204.—Lister's splint for resections of t wrist.

leaves, and the bark of trees. According to the same authority, tl Turks use moulded wooden splints made of the fibrous portions palmetto leaves sewed to thin leather, thus obtaining a material whi can be applied to an injured limb either circularly or in the form of

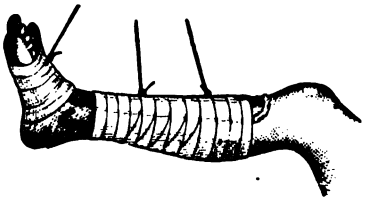


Fig. 205.—Volkmann's dorsal splint (for suspension).

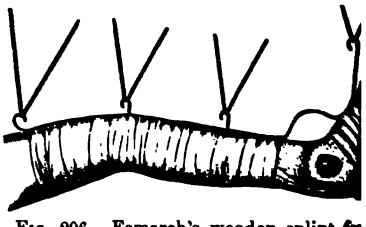


Fig. 206.—Esmarch's wooden splint fo resections of the ankle.

gutter. Martini and Gooch glue narrow, thin strips of wood tak from the linden tree close together upon soft leather, and in this w a splint can be made which is an excellent temporary dressing for fracture, particularly of the low extremity. Esmarch's splint m terial, which can be cut into a required size, is very similar to th (Fig. 207). It consists of strips wood three centimetres wide a one and a half centimetre thic which are glued between two laye of cotton cloth. Herzenstein a vises that splints be made after the fashion of the ordinary trellis wo used for supporting vines. Reeds, willow withes, and straw made in mats have also been recommended as splints. Thin, pliable strips

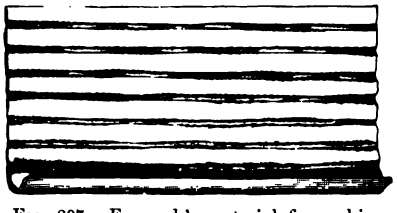


Fig. 207.—Esmarch's material for making splints.

wood about three to four centimetres wide make a very good material for splints when combined with plaster bandages, and are also very useful for immobilising a joint after an antiseptic dressing has been applied.

Wood Dressings.—Waltuch recommends wood dressings made of shavings, 4.5 centimetres wide and 0.5 to 1 millimetre thick, and any desired length, which are prepared by planing pine planks in a particular way. The wood shavings roll up spontaneously like a bandage, are more easily handled than thin board splints, and much cheaper than the latter. This wood dressing, consisting of shavings bound together with glue, is suitable for corsets, for encasing a limb, etc. (Wien. klin. Wochensch., 1888, No. 10.)

Papier-maché Splints.—Splints made of stout papier-maché, about three millimetres thick, are very frequently employed for immobilising purposes. These splints are usually made with flat edges, which may be bent into any required shape, or else flat pieces are used of varying widths. After dipping this material in warm water just before it is to be used, it becomes soft, and can be readily made to fit any part of the body when fastened on with a bandage. The small papier-maché splints are chiefly used for strengthening dressings in which starch is employed.

Metal Splints.—Metal splints are generally made of iron, sheet iron, tin, zinc, telegraph wire, wire gauze, etc., and may be stiff and unyielding or capable of being bent into any shape. Volkmann's sheet-iron splint (Fig. 208) is exceedingly good, and in very general use for the lower extremity. It is a good plan to make this of two parts—an upper and lower—for lengthening and shortening the splint any necessary amount (Mügge). Metal splints which are capable of being bent into any shape are best made of telegraph wire, tin, zinc, or galvanised iron. Flat splints, made of thin tin plate, have been recommended by Solomon and introduced in the Danish army; they are thirty-five centimetres long and ten centimetres wide, having at one end two small, three-pronged projections, which are hook-shaped and notched, and at the other two clefts, into which the projections are inserted and secured, thus rendering it possible to make a splint of any desired length. Thin galvanised iron which is capable of being cut with shears has been recommended, especially by Schön and Weissbach, as a material suitable for splints. Schön gives directions for making excellent splints in a very short time from this sub-

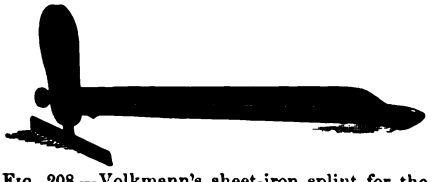


Fig. 208.—Volkmann's sheet-iron splint for the lower extremity.

stance, and hinge joints, fenestræ, and interrupted spaces can be inserted. In Fig. 209 is represented a simple way of making a gutter splint for the arm and leg.

The gutter splint for the arm (Fig. 209) is made by cutting out a splint of the desired size and bending it on its long axis so as to form a shallow groove, and then transversely so as to make an obtuse or right angle.

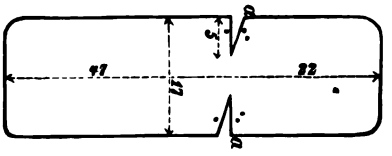


Fig. 209.—Pattern for making a tin gutter for the arm (Schön).

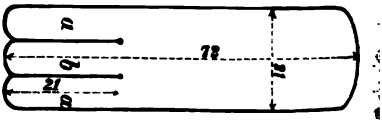


Fig. 210.—Pattern for making a tin gutter for the leg (Schön).

Strings are passed through the punctures at *a a*, and tied to maintain the splint at the proper angle. The gutter splint for the leg is cut from galvanised sheet iron, as represented in Fig. 210; it is then bent on its long axis into a half circle, and the foot-piece is formed by bringing the lateral parts *a a* around behind the middle part, and retaining them in this position by strings or wires.

Aluminium Splints.—Stendel has devised a pair of shears for cutting aluminium plate into the proper shape. The splints of aluminium have the advantage of being cheap, light, and pliable.

Wire Splints, made from properly bent telegraph wire or from wire netting, are used a good deal. Telegraph wire is chiefly used at present for making suspension splints, and in the preparation of the interrupted plaster splint (Figs. 221–223). One of the best-known kinds of wire splint is Smith's (Fig. 211), which is especially well suited for the treatment of compound fractures of the lower extremity. It is made of two nearly parallel bars joined at their extremities and in the

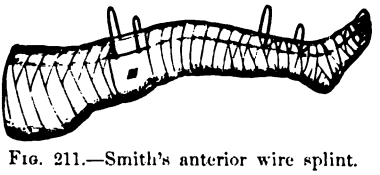


Fig. 211.—Smith's anterior wire splint.

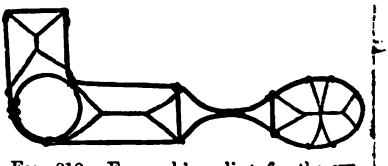


Fig. 212.—Esmarch's splint for the arm, made out of telegraph wire.

intervening space by from two to four movable wire arches or hoops, to which are attached the ropes for suspending the splint. At three places—namely, over the ankle, knee, and hip joints—it is slightly bent, and is then applied to the anterior surface of the limb, to which it is secured generally by a plaster bandage.

ıarch has constructed a splint (Fig. 212) of telegraph wire for per extremity, which approaches the character of the splints f wire gauze gutters for the and lower extremities (Figs. 7). Woven wire is also used ıing splints which can be bent ferent shapes. Esmarch has ıended the use of long strips lattice for splints, and from terial it is very easy to make similar to Bonnet's stocking. 's lattice-work splint, made wire tinned over, is exceed- ;ood both for ordinary prac- d for army surgery. These can be bent into any shape, ı be made to fit over any g or any part of the body 13), and they can be length- y fastening one or more to- By taking out some of the ieces and bending the lateral e splint can be made inter- or can be bent at any angle 13, *d*, *e*). Neuber has recom- l splints made of glass (Figs. 5), as particularly good for where an antiseptic dressing in place for a considerable They are transparent, and permit all parts of the dressing to be ed without disturbing the limb.

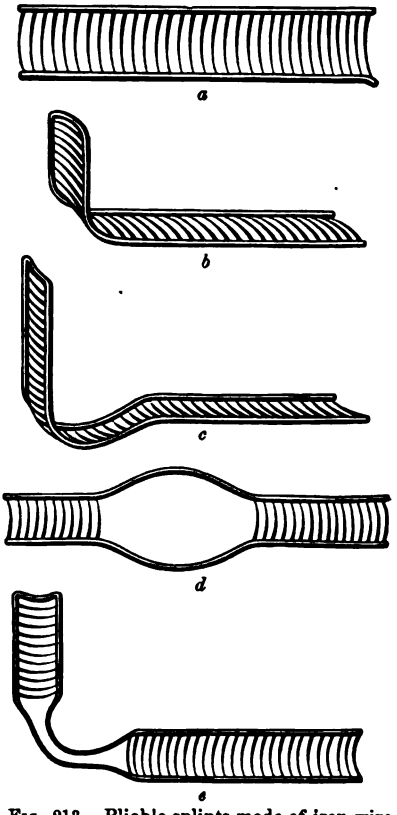


FIG. 213.—Pliable splints made of iron wire tinned over (Cramer).

tic Splints.—Moulded splints are prepared by wetting or heating terial of which they consist, and when it has become soft and

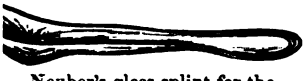

.—Neuber's glass splint for the upper extremity.

FIG. 215.—Neuber's glass splint for the lower extremity.

t is made to fit snugly over some particular portion of the body aid of a roller bandage. After the material becomes dry or

cold, whichever the case may be, a hard, unyielding splint results which fits very closely.

Papier-maché.—In the preparation of these splints ordinary papier-maché can be used, though it possesses only a moderate amount of firmness when dry. The prepared papier-maché of P. Bruns is better, and consists of ordinary papier-maché which has been impregnated with some hardening substance, generally shellac. When this preparation is warmed in a hot oven, or wet in boiling water, it becomes soft, and capable of being moulded into any shape in a very few minutes, and subsequently becomes as hard as wood in from five to ten minutes.

Plastic Felt.—Pliable felt can be used in a similar manner, and P. Bruns describes its preparation as follows: A sheet of ordinary felt, from five to eight millimetres thick, is soaked in a solution consisting of one part shellac to one and a half parts of alcohol until it has become completely saturated, or until the felt will absorb no more of the solution. (It takes up about four times its own weight.) It is then allowed to dry, and from this material excellent splints can be made in the shape of flat strips, or gutters, or cases. After cutting the piece of plastic felt into the proper shape, it is dipped into water which is almost boiling, or stroked with a hot flat-iron or laid on a hot stove-lid, which causes it to become as soft as any ordinary unimpregnated felt. The softened felt is then applied with a roller bandage to the limb, which has been previously covered with a bandage or with cotton, and in a short time this splint becomes as hard as a board. F. Schwarz has used moulded felt in Billroth's clinic, as a substitute for more expensive and complicated contrivances, with the very best results (Wien. med. Wochensch., 1886, No. 37). Splints of stiff black caoutchouc are very serviceable. They can be softened in hot water and given any desired form.

Gutta-percha.—Gutta-percha can be used in a similar manner for making straight, gutter, or case splints. Gutta-percha, or the dried sap of an East Indian tree (*Isonandra gutta*, Sapotacee), was introduced in Europe in 1843, and was first used for treating fractures in England in 1846, though it had been employed for this purpose in Borneo a long time previously. When gutta-percha is warmed in hot water it becomes soft and capable of receiving any shape, and then hardens when it cools off, in about fifteen minutes. For making straight, gutter, or case splints of gutta-percha, sheets of this material are cut into the proper form and softened by immersion in water at a temperature of 75° to 85° C. The splint is then allowed to cool off slightly, and after being modelled into the shape required to fit the particular extremity, which has been previously encased in a flannel bandage, it is kept in place by

a wet roller bandage. By gluing together the edges of two gutters a circular splint may be made. Gutta-percha is not affected by water, blood, pus, or urine, but it is expensive, and on this account has not been very generally used.

Leather.—Ordinary leather is an excellent material for making straight or case splints; it should be soaked in water and applied to the limb with a roller bandage while in a wet condition, when it is capable of being moulded.

Cellulose Splints.—R. de Fischer has advised the use of a hardening material for splints made of cellulose. Thick flat plates of cellulose are manufactured for this purpose having the outline of the different limbs, and strengthened on one side with water glass. This side of the splint is then, before use, painted over with nearly boiling water, which causes the material to become immediately soft and pliable. The splint is applied wet side out, and fastened in position with gauze bandages which have been saturated with cold water. These splints can be strengthened by impregnating them with water glass on both sides. They are said to possess the advantage of simplicity, rapidity in hardening, lightness and durability, and, furthermore, cost very little. They are manufactured by the apothecary in Triest, Karl Zanetti. Landerer, Kirch, and others recommend celluloid splints. They are made of celluloid bandages, which are gauze bandages impregnated with a solution of celluloid in aceton (1 to 3). One disadvantage is that the material is inflammable.

Extension Splints.—Before the introduction of extension by weight, extension splints were employed, and they will be referred to in their proper place.

Articulated Splints.—Jointed splints are those consisting of two or more ordinary splints united by a joint or some material capable of bending, such as caoutchouc, cloth, leather, etc. A jointed splint can be fastened at any desired angle, or can be left movable, permitting free motion in the extremity to which it is applied.

Fig. 216.—Heine's disjointable articulated splint for the upper extremity.

There is a great variety of these articulated splints, the best one probably being Heine's (Fig. 216), though Bidder, Lücke, and others have constructed very excellent splints. These articulated splints can be used for exerting a gradual extension on contracted joints, for overcoming contractures of the muscles and soft parts, and for the after-treatment of resected joints as a supporting apparatus.

Stillmann has also recommended an excellent adjustable brace, which permits motion in the joint to which it is applied, and which can be readily included in a plaster dressing (Figs. 217, 218).

Improvised Dressings of the Battle-field.—In times of war it may become necessary to improvise dressings and splints out of whatever materials may be at hand. J. Port has written a book on this subject

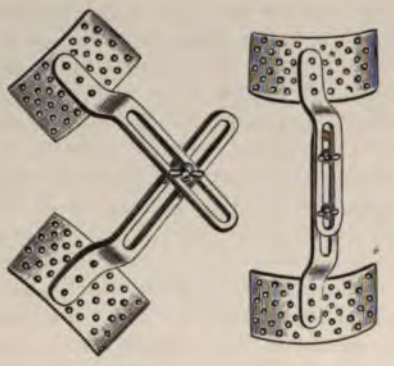


Fig. 217.—Adjustable clamp apparatus.

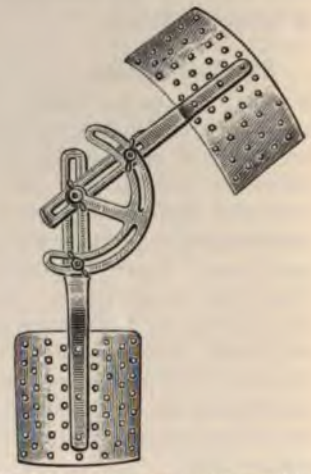


Fig. 218.—Clamp apparatus provided with a joint.

(Stuttgart, Ferd. Enke, 1892), in which are a number of illustrations and descriptions of materials which can be used as surgical dressings.

Apparatus for Home Gymnastics.—Brief mention should be made in this place of the different kinds of apparatus used for gymnastic purposes which should always be found in every hospital. It would take too much space to describe them except in a very general way. The machines invented by Zander, of Stockholm, afford many kinds of gymnastic exercise which are exceedingly useful in some cases, and their place cannot be supplied by either massage or passive motion. New and simplified apparatus are constantly being constructed for carrying out active, passive, local, and general movements. These gymnastic apparatus are coming more and more into use in hospital and private practice.

CHAPTER V.

THE APPLICATION OF IMMOBILISING DRESSINGS MADE OF MATERIALS WHICH GRADUALLY HARDEN.—THE APPLICATION OF EXTENSION APPARATUS.

Plaster dressings.—Dressings of tripolith, starch paste, water glass, gutta-percha, and felt.—The methods of employing extension.

§ 54. **Immobilisation Dressings of Hardening Substances.**—Dressings for producing immobilisation are used for fractures, inflammations in joints, and after many operations—for example, in the after-treatment of resections and osteotomies, etc.; they serve the purpose of preventing movement in the part of the body under treatment. Even in ancient times attempts were made to form immobilisation dressings from substances which would subsequently harden, but the methods were imperfect. To Larrey, the distinguished army surgeon of Napoleon I., belongs the honour of having generally introduced those immobilising dressings which were applied in the soft state and then allowed to harden. Larrey soaked the dressings for twenty-four to thirty-six hours in a mixture made of albumen, liquor plumbi subacetatis, and spirits of camphor. This somewhat tedious procedure was supplanted by the starch dressing invented by Seutin in 1834. As the starch dressing took a long time to harden, attention was directed to some more rapidly hardening material, and gypsum was taken up, a substance which had been employed by the Arabian physicians. The honour of introducing the gypsum dressing and the methods of applying it is due to the two Dutch physicians, Mathysen and Van der Loo. Numbers of other hardening substances, such as water glass, tripolith, etc., have also been used in the same way.

The Plaster-of-Paris Dressing.—Among all the materials employed for making an immobilising dressing there is none better than gypsum, possessing, as it does, the power of rapidly becoming hard. Gypsum, or plaster of Paris, is hydrated sulphate of calcium ($CaSO_4 + 2H_2O$). The gypsum used in dressings is burned or dehydrated, and after mixing it with water it hardens in a few minutes to a solid mass, forming with water a firm chemical combination. The plaster dressing can be

applied in many different ways, the best being in the form of plaster bandages. For this purpose bandages, preferably of gauze, are impregnated with dry gypsum powder by rolling them in the latter and working it into the meshes of the gauze. Soft mull bandages can also be treated in the same way. The application of the gypsum dressing is begun by smoothly enveloping the particular portion of the body with a soft mull or flannel bandage, or with a thin layer of cotton, over which is placed a soft mull bandage. In emergency cases the extremity may merely be greased with oil, lard, or vaseline, to prevent the plaster from sticking to the hairs; bony projections should be covered with a little cotton, to avoid pressure at these points; and, above all, one must be careful to apply the bandages loosely, so that after drying they do not become too tight. Cotton hose can also be used beneath the gypsum; it is drawn over the extremity like tights; it is cheap, and fits exceedingly well without forming wrinkles. When necessary, two or three layers of this material may be put on over each other. The roller gypsum bandages are then allowed to soak in water about a quarter of a minute, or until no more air bubbles are given off. The bandage is then squeezed dry and applied to the part in question as loosely as possible. It should never be drawn tight, as this will cause the bandage to become too narrow, and may subsequently impede the circulation in the limb. There is no need of making a reverse with the gypsum bandage, as a few wrinkles do no harm and can be smoothed out by rubbing the bandage with the hand, and thus causing the dressing to conform accurately to the shape of the limb. After about three or four layers of gypsum bandage have been applied, a thin layer of gypsum paste can be added; it is made by mixing together gypsum powder and water in about equal proportions. This layer is spread on and smoothed over with the palm of the hand, the smoothing process being continued until the dressing looks as though made in one piece. The gypsum paste should not be put on too thick, for fear of making the dressing very heavy, and I frequently do not use it at all. Plenty of bandage and not too much plaster is my maxim. The edges of the dressing are best treated by turning up the projecting underlying material (cotton or bandages) like a cuff and securing it to the outer surface of the splint with a turn of the plaster bandage or a little of the paste.

Even while the bandages or outer layer of plaster paste are being smoothed down with the hand, it will be noticed that the dressing has become firmer. In the next few minutes it becomes noticeably warm and at the same time perfectly hard, but not till two or three hours later will the dressing be completely dry. By the addition of some

ine substance, like chloride of sodium or alum, the hardening ypsum can be accelerated. If it is desired to make the plaster · water-tight, its external sur- be painted with a solution of ether—one to four (Mitscher- · a water-glass bandage may l over the gypsum; this latter is the best. It makes the gyp- ssing, particularly when ap- children, exceedingly durable.

Fig. 219.—Thin strips of wood used for strengthening a plaster-of-Paris splint.

easing the strength of the plaster dressing the latter is often include thin, pliable strips of wood (Fig. 219), or splints made of papier-maché, wood, zinc, or wire. If it is not desirable to cover in some portion of the body by the plaster dressing on account of wounds, fistulæ, etc., a fenestrum (Fig. 220) can be cut out

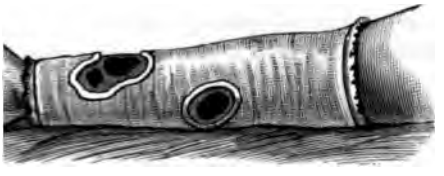


Fig. 220.—Fenestrated plaster splint.

portion, the location of which may be previously indicated by over it a piece of cotton or a flat disk having a projecting he edges of the feneson be smoothed off with plaster paste or asphalt- to prevent fluids such om gaining access to the urface of the dressing. considerable portion of mity, such as the knee- -joint, is to be left out of the splint, two plaster cases should be applied, one, for example, to the thigh, the other to the leg, joined together by an iron rod, which can also be covered with plaster (Fig. 221); telegraph wire can be used in the same manner. Under other conditions, when, for instance, one wishes at the same time to suspend the extrem-

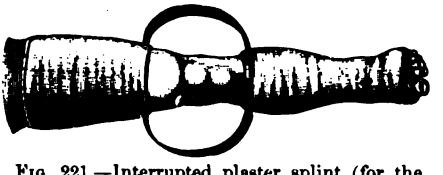
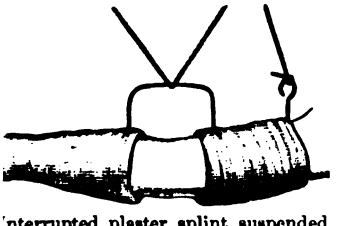


Fig. 221.—Interrupted plaster splint (for the knee).



Interrupted plaster splint suspended (upper extremity).

her plan is carried out which is represented in Figs. 222 and wo plaster cases are applied to the extremity while it lies upon

a suitable splint, and a piece of telegraph wire, having been bent into proper shape, connects the two separate bandages on the dorsal surface of the limb (see Figs. 234, 235, 236). In the same way two plaster cuffs can be provided with a hinge so as to form a joint, which is useful in the after-treatment of a resected elbow.

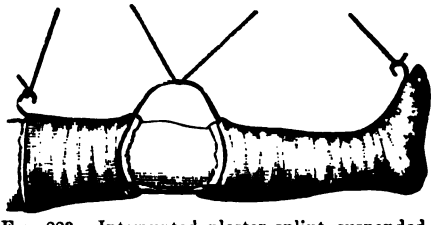


FIG. 223.—Interrupted plaster splint, suspended (lower extremity).

Gradual stretching of Contracted Joints by the Plaster Dressing.—The plaster dressing can also be used for gradual extension of contracted joints. A plaster case is applied to the lower extremity and an oval-shaped fenestrum cut over the region of the anterior surface of the knee, and at the same time the splint is cut behind transversely across the popliteal space. Day by day continually larger pieces of cork are then wedged into the posterior line of division in the splint, and thus the knee-joint is gradually extended.

Gypsum Dressing combined with an Antiseptic Dressing.—The great advances in modern aseptic surgery render possible the frequent combination of plaster with antiseptic dressings. After osteotomy, for instance, of the tibia, we cover the open wound with an aseptic protective dressing and then apply over this a plaster splint, which is left undisturbed till the wound has healed, or from four to six weeks. We often adopt a similar practice in the after-treatment of resected joints, allowing the wound to remain partially open. In other cases of joint resection the plaster bandages are not placed over the antiseptic protective dressing till about three to five days after the operation, when the drains are taken out. In compound fractures the plaster splint is combined with the antiseptic dressing at the earliest possible moment. Bergmann's and Reyher's experiences show that gypsum dressings will become of the greatest use in army surgery. These surgeons obtained most excellent results, during the Russo-Turkish war, from combined antiseptic and plaster dressings for the treatment of gunshot wounds of bone. In addition to the plaster-bandage dressing, as it is ordinarily described, mention should be made of the following modifications:

FIG. 224.—Plaster splint.

FIG. 225.—Case for the lower extremity, with straps, buckles, and a hinge-joint on the opposite side.

Modifications of the Gypsum Dressing.—Compresses, pieces of cloth, or parts of the patient's clothing, may be dipped in plaster paste and either laid around an extremity or fastened on with bandages after previously enveloping the limb in some buffer dressing. These gypsum cataplasms are highly recommended by Pirogoff, Adelmann, Szymanowski and others for making

hasty dressing to suffice during transportation of the patient. Strands of hemp may be dipped in plaster paste, fitted to the extremity, and secured with a dry gauze bandage. Other materials can be soaked in plaster and used as splints —e. g., strips of cotton cloth, muslin, felt, oakum, etc. Cotton filled with plaster, or the plaster plates of Fickert, are dipped in hot water and then applied to the limb. They harden in eight to ten minutes. Plaster beds for spondylitis (see Fig. 226), and plaster suits for spondylitis and coxitis, were quickly made from the different materials soaked in plaster. Gypsum powder is also sewed up in a sack, and when soaked in water it forms a mass which readily becomes moulded to the limb, and when dried makes a splint which can easily be taken off (Zsigmondy). By sewing together two of these sacks full of plaster longitudinally upon one side and laying them around an extremity and then wetting them, a gypsum splint is formed having the sewed connection between the two bags as a hinge to facilitate its removal from the limb. The same result can be obtained by sewing together two pieces of cloth longitudinally, and putting gypsum powder between the two layers. These are then applied about the extremity and moistened with

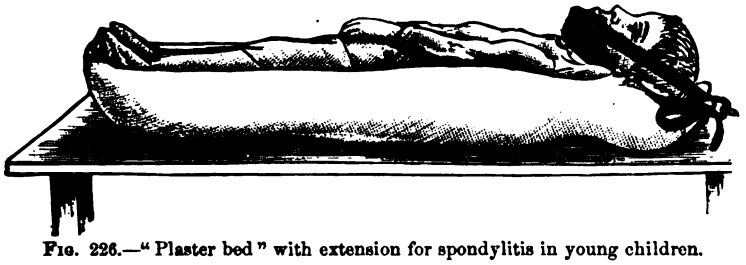


Fig. 226.—"Plaster bed" with extension for spondylitis in young children.

water. In a similar manner immobilisation appliances can be made in two or more parts which can be fastened on a limb with bandages or secured with straps and buckles (Fig. 225). In this way most excellent splints can be fashioned of gypsum or other hardening material, such as water glass, and also many kinds of supporting apparatus can be substituted for those manufactured by instrument makers.

Auschütz advises that the straw splints which have long been employed by stretcher bearers as a transportation dressing be soaked in plaster paste and bound on with a wet gauze bandage.

Back Support.—For the application of the plaster dressing to the lower extremity, and particularly to the thigh and pelvis, extension and supporting appliances are of great utility. They render the pelvis accessible on all sides, and prevent a fractured femur from becoming shortened. The simplest form of pelvic support is represented in Fig. 142; it is Volkmann's cushioned support, which is placed under the sacrum. A footstool used in the same way forms an excellent back rest. The patient is secured in the horizontal position, with extension applied to the leg and counter-extension to the axilla.

Extension appliances are sometimes very useful accessories in plying a plaster splint to the thigh, especially if the fracture is obli and there is marked shortening. Lücke, Heine, and Bruns have vented extension appliances for this purpose. Pulleys were once us particularly for the lower extremity, in the application of plas splints. Special contrivances for extension are, as a rule, unnecessa and the hands of an assistant will ordinarily be found sufficient. P tative plaster splints are used good deal for fractures and d eases of the lower extremity. F particulars, see Regional Surge Plaster dressings are applied to t thorax for injuries and diseases

Fig. 227.—Plaster dressing taking in the head, neck, chest, and pelvis for tubercular disease of the spine.

Fig. 228.—Plaster dressing, taking in th shoulder, thorax, and arm for fracture of the upper part of the humerus.

the spine (Fig. 227) and for fractures of the upper end of the humer For particulars, see Regional Surgery.

Removal of Plaster Splints.—Plaster splints or dressings are tak off with the assistance of a knife made especially for the purpose (F 230), with shears, or a saw (Fig. 231). The plaster knife should held with its edge somewhat at an angle to the splint, so as to cu obliquely to the external surface; or two oblique longitudinal incisi are made in the plaster forming a V-shaped groove. The dee layers of the splint should be cut with the plaster shears. By m tening the whole splint with water, or only along the line where it i

e cutting process is made much easier. After the plaster as been cut through longitudinally, the edges of the incision apart and the limb is lifted out. Plaster splints which have nd taken off may, ired, be replaced again. In such best to connect with plaster paste ve plaster, over ster paste is ap- thus the edges of are less likely to parated.

FIG. 229.—Knife for plaster dressing.

FIG. 230.—Shears for cutting splints.

FIG. 231.—Plaster saw.

h Dressing.—Lang- recommended trip- bstitute for gypsum f Paris. Tripolith h, cement-like sub- sisting of gypsum silicate of alumin- arcoal or coke. The f tripolith are in general the same as dehydrated gypsum, but cording to Langenbeck, is somewhat lighter and cheaper than also hardens a little more rapidly, and when hard will not absorb tripolith dressing is applied with bandages, like plaster of Paris.

rch Dressing.—Starch paste was recommended by Seutin, in the manufacture of stiff dressings. A starch dressing is ied, agreeable to the patient, cheap and light, but it has the ge of requiring from one to three days to become dry, and son starch dressings have been supplanted by plaster in the of fractures. The starch bandage is frequently combined board splints in fracture of the arm, and is also used alone in eatment of any fracture.

ethod of applying the starch bandage is briefly as follows: is laid on the skin in the shape of a flannel bandage, and rominences are protected from too much pressure from the sing by a layer of cotton. A soft mull bandage is applied annel, and then a layer of starch or bookbinders' paste is r the mull. Several strips of pasteboard of various sizes are oft and pliable by soaking in warm water, and are included sing in such a way as to incase the limb, leaving short inter- en each strip. The pasteboard is then covered evenly with paste, and over this is placed a mull bandage, which receives

another layer of starch paste. Some three or four layers are enough, and the strips of pasteboard can be used in a double layer, especially if they are narrow. Finally, a dry mull bandage is applied to prevent the starch paste from adhering to the clothes, or a bandage in the form of a bag may be used, as well as black silk, to improve the appearance of the dressing. The dressing is cut open with a stout pair of shears, and can then be used as a removable splint in the same way as described for the plaster splints (Fig. 225).

Cotton-Starch and Paper-Starch Dressing.—The cotton-starch dressing of Burggraeve and the paper-starch dressing of Laugier and Heyfelder are modifications of the ordinary simple starch dressing. The latter is made by including strips of paper in the bandages and covering them with starch paste. In the cotton-starch dressing the limb is enveloped in from two to four rather thick layers of cotton wool, over which is applied the starch-paste dressing, with strips of pasteboard softened in warm water, and made to fit the extremity by wrapping over them a mull bandage in the manner just described.

The Water-Glass Dressing (Schrauth, Schuh, 1857) is very easily put on, is cheap, durable, hard, and light, and is also impervious to water, but has the disadvantage of requiring twelve to twenty-four hours to harden. It is best to use a freshly made solution of neutral silicate of potassium having a specific gravity of from 1.35 to 1.40. This dressing, like the plaster of Paris, is applied in prepared bandages which have been saturated with water glass having the consistence of syrup. About five to six layers of the water-glass bandages are sufficient. It is best to use a flannel bandage, or cotton and a mull bandage, as padding to lie beneath the water-glass bandages. The skin should be carefully protected from contact with the water glass, as the latter is liable to cause a very obstinate eczema, particularly when old solutions are used. Furthermore, the water-glass bandages should not be carried beyond the limits of the protective padding, as the sharp edges of the splint may cut into the skin. The water-glass splint can also be strengthened by including in it thin strips of wood or other material. It is an excellent plan to mix with

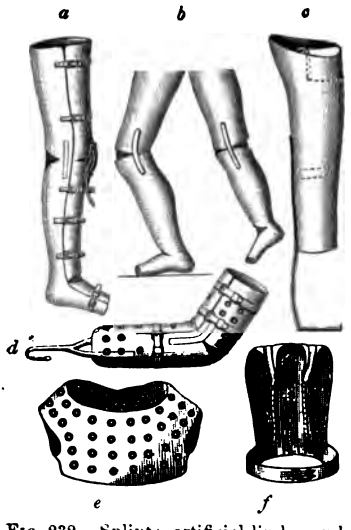


Fig. 232.—Splints, artificial limbs, and corsets, made of water glass.

the water glass, gypsum, chalk, cement, etc. These substances make the dressing harden more rapidly and render it very firm (Böhm, König, the author). Bandages are soaked in the thick paste and applied as in the plaster dressing, or the paste made from water-glass powder is applied with a brush to the bandages after they have been put on. At the end the entire dressing can be dusted with the dry powder and painted over with alcohol, which gives it a hard, glassy covering. The water-glass splint is much used in the treatment of inflamed joints, fractures, etc., and can also be made into hinged, removable splints. Kappeler and Hafter have shown that a number of apparatus, artificial limbs, corsets, articulated splints, etc., can be made of water glass* (Fig. 232). Fig. 232, *a* and *b*, represent water-glass splints for the lower extremity, provided with straps, buckles, strips of caoutchouc, and fenestra suitably placed for permitting movement of the joints; *c* is a contrivance of Taylor's for use in coxitis (see Regional Surgery); *d* represents a prothetic apparatus for amputation of the arm; *e* is a corset, and *f* is another of Taylor's devices for kyphosis; *d* and *e* are perforated with holes, to make the apparatus light and accessible to air.

The manufacture of immobilisation appliances from moulded felt and gutta-percha has been described before (see pages 213, 214).

Dextrine Dressing.—Among the other materials which have not found any very general use brief mention may be made of the dextrine dressing of Velpeau (1838). It is applied in the same manner as the starch dressing, one hundred parts of dextrine being mixed with sixty parts of spirits of camphor and fifty parts of water. This dressing takes from four to seven hours to dry.

Glue Dressing.—The glue dressing (Vanzetti, 1846) hardens very slowly. Strips of linen or roller bandages of linen or muslin are spread on one side with joiner's glue, allowed to dry, and then rolled into bandages with the glue side out. The bandages immediately before use are dipped in hot water and applied to any desired region over a protective padding bandage. The same procedure can be adopted as in starch or water-glass dressings, which consists in simply saturating bandages and splints with the glue after they have been applied. Thin wooden or pasteboard splints can be incorporated in the dressing to strengthen it.

Magnesite Dressing.—The magnesite dressing is most excellent, firm, and durable. Finely powdered magnesite and water glass are mixed into a thick paste. The method of applying this dressing, which requires some twenty-four to thirty-six hours to dry, is practically the same as for the starch or water-glass dressing—i. e., either the magnesite water-glass paste is painted with a brush over the dry mull bandages, or else the mull or cotton bandages

* For the further description of these appliances, see Kappeler and Hafter, Deutsch. Zeitschr. für Chir., Bd. vii., p. 129.

are first soaked in the paste and then applied to the extremity over a padding of flannel bandages.

Cement Dressing.—In the application of the cement dressing a mixture of one part of cement to two to three parts of gypsum is employed, and this is then applied like the gypsum or plaster-of-Paris dressing.

Other Dressings.—The gum dressing (Lorinser) is made of lime or cement dissolved in casein, albumen, gum arabic, glue and other materials by the addition of water.

The gum-chalk dressing of Bryant and Wölfler is made of a paste of gum arabic and chalk powder. There is also a collodion dressing, a resin dressing, with or without wax, a paraffine and stearine dressing, but so far all these have not come into general use. There will be described in Regional Surgery other materials which are used in the preparation of jackets for scoliosis and kyphosis, but which may also be used for splints on the extremities. Heusner uses twisted steel wire for splint purposes.

§ 55. **The Method of employing Extension by a Weight.**—As we shall see later on, permanent extension is much used—for example, in chronic inflammations of joints and in fractures. The method of applying extension by a weight is the most generally used of all, and for this we have to thank the American surgeons Buck, Crosby, and others, as well as the German surgeons Volkmann and Bardenheuer. The pulling of the fragments apart by a weight is very frequently used for the lower extremity in fracture of the femur and for diseases of the hip and knee joints, and consequently we must describe it somewhat at length.

Extension of the Lower Extremity.—The extension dressing for a fracture of the neck of the femur in the form of an adhesive-plaster extension contrivance is begun in the case of adults with the application of a strip of adhesive plaster, from three fingers to a hand-breadth in width, along the inner and outer side of the leg, in such a way that the middle of the strip extends in the form of a loop about a hand-breadth beyond the sole of the foot. Before applying the adhesive plaster it is a good plan to shave off the hairs, to prevent the latter from sticking to the plaster; then strips of adhesive plaster (or a flannel bandage) are placed circularly around the leg over the lateral strips at intervals, or overlapping each other, beginning just above the malleoli and going to the head of the fibula. The free ends of the adhesive plaster, which should reach to the middle of the thigh, are then split longitudinally with scissors into two or three strips, which are turned down from the thigh and also secured about the leg with several circular strips of adhesive plaster.* In this manner the lateral strips of

* In this country the strips are not turned down, but left applied to at least half the length of the thigh above the knee, to lessen the traction on the ligaments of the knee-joint.—[*Trans.*]

: plaster are secured to the leg very firmly. I avoid placing ircularly around the leg in the region of the head of the fibula, ›ractice sometimes has been known to cause a pressure ; of the external popliteal nerve. In the loop made adhesive plaster below the foot a small piece of fastened in place to prevent chafing of the skin over eoli. Through ı the centre of 'd is passed the which the ex- weight is at- The rope is to the board ting it on the :t the foot, or simply be at-

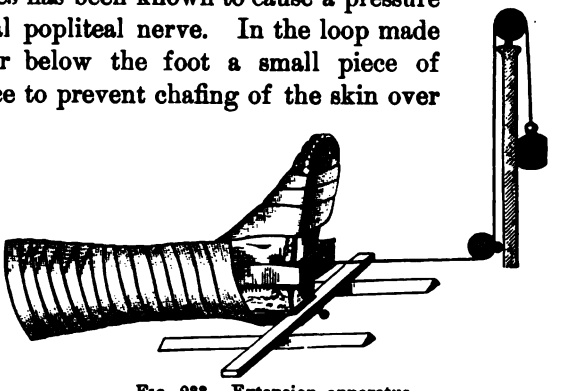
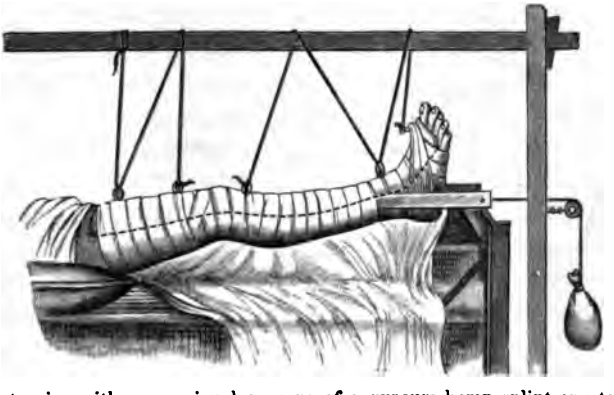


FIG. 233.—Extension apparatus.

›y a hook (Figs. 233, 235). The rope to which the weight is for making the extension runs over two rollers fastened to the bed (Fig. 233). This dressing can be made more firm and by applying over it a layer of mull bandage, and over this a ındage, or, better still, a water-glass or chalk-water-glass dress- › lessen the amount of the chafing to which the limb is sub- ınd to regulate the position of the foot, it is a good plan to use



Extension with suspension by means of a gypsum-hemp splint or a telegraph-wire splint for fractures of the femur.

ın's sliding foot rest (Fig. 233), which consists of a tin gutter r the leg, padded with cotton or jute, and having a removable :e attached to a wooden cross-bar. The cross-bar slides on ;itudinal strips of wood. Other sliding foot rests have been

invented by Riedel and Wahl. If Volkmann's contrivance is ployed, any hardening dressing, such as the water-glass bandage, r

FIG. 235.—Vertical suspension with a plaster dressing, the knee being bent at a right an

of course be applied so as to include the leg splint. The weight of body is ordinarily employed for making counter extension, the pat being kept, if possible, in the horizontal position while the foot of bed is raised by a couple of blocks of wood; (pelvic or perineal girdle, made, for example, fro rubber bandage, can be carried around the patie perinæum, thence to the head of the bed, and attac to a weight by a cord running over a couple of roll

As adhesive plaster is sometimes uncomforta and may cause a troublesome eczema, emplasti cerussæ may be used in its place; or perhaps a be plan is to enclose limb in a flannel ba age, and to attach this extension st made of pieces of li cloth; or a strong not too elastic rul bandage may be se laterally to the tı of the flannel band Personally I find

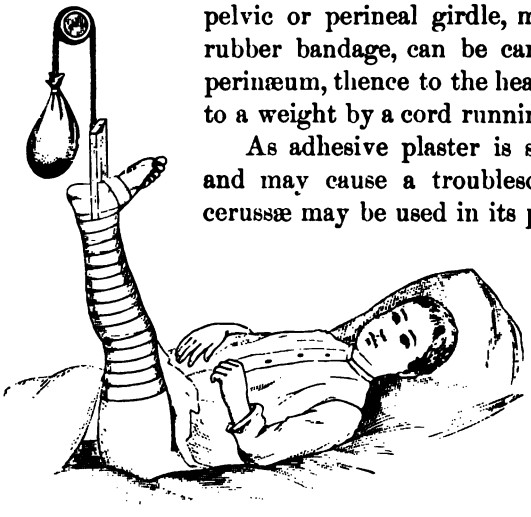


FIG. 236.—Vertical suspension for fractures of the femur in children.

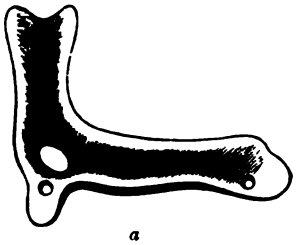
following method of applying the extension apparatus much sim than the one just given. Two long strips of sole felt, or piano

or buck-skin are cut to correspond to the length of the limb and from 6 to 10 centimetres in width. The two lower ends are joined together by a strip of canvas. The two strips of felt are secured by an adhesive material, which is applied to the sides of the leg, and by circular turns of a bandage. The constituents of the adhesive material are as follows: ceræ flavæ, resin, damarak, colophon, āā 10.0; terebinth. 1.0; ether, alcohol, oleum terebinth. āā 55.0. This mixture is filtered. In from two to three hours the felt or buck-skin strips are firmly adherent to the leg, and the extension can then be begun in the way described above. Extension may also be combined with some one of the various kinds of immobilising dressings, such as plaster of Paris. Recently the cord for exerting the traction has been attached by means of hooks and cross-bars to rubber tubing filled with air applied around the region just above the malleoli.

Fig. 237.—Extension at the shoulder by a weight.

In the after-treatment of cases, such as a hip-joint resection, where extension is only required at night, gaiters are applied reaching to the middle of the thigh and having a leather foot-piece to which is fastened the cord for exerting the traction.

If it is desired to apply extension to the thigh in a somewhat abducted position, as after resection of the head of the femur, rollers can be attached to a board, which may be fastened with screws to any de-



a

b

Fig. 238.—Extension on the upper arm: *a*, gutter splint; *b*, splint with weight extension.

ed part of the bed, while the cord for exerting the traction is carried over a wooden frame placed near the bed.

Frequently, in cases of fracture of the lower extremity, extension i combined with suspension, as illustrated in Figs. 234, 235, and 236. I requires no further explanation.

Extension of the Upper Extremity is carried out by means of adhesiv plaster applied to the shoulder-joint and arm, according to the methoc of Bardenheuer and Hamilto or of Lossen or Hofmokl. E tension upon the upper extrem ity has by no means the im portance that it has upon th lower. Hamilton's extension a the shoulder-joint (Fig. 237) i applied by means of adhesive plaster and a weight, while counter extension is made with a crutch in the axilla, the crutch being supported by a belt around the waist. Lossen's extension for the arm (Fig. 238) is applied by laying the arm on a splint which is fastened to the patient's bed. The way in which the traction is exerted by adhesive-plaster strips is represented in the figure and needs no further description. Hofmokl has also devised an excellent apparatus for applying extension by a weight to the upper extremity (Fig. 239). There is seldom any need of applying extension at the elbow-joint, but for the forearm and wrist-joint Langenbeck's

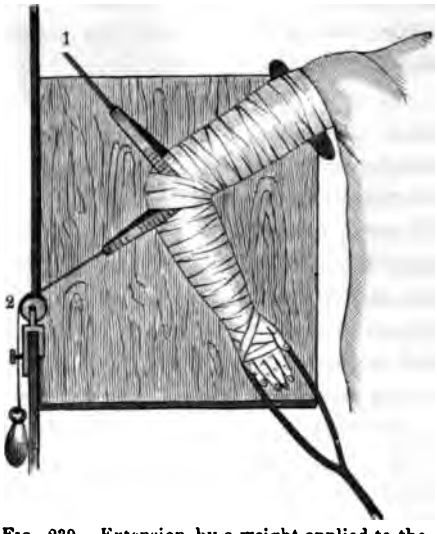


Fig. 239.—Extension by a weight applied to the upper extremity (Hofmokl). In extension by weight of the upper arm the loops 1 and 3 are not used; in case of the forearm 2 is not used; the extension is then made at 3 and counter extension at 1.

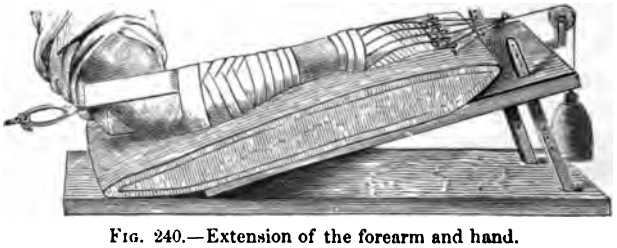


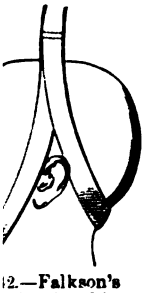
Fig. 240.—Extension of the forearm and hand.

method (Fig. 240) can be used. Extension by a weight can also be employed for the metacarpus and fingers by means of loops of adhesive plaster. Extension by suspending the arm is illustrated in Fig. 194.

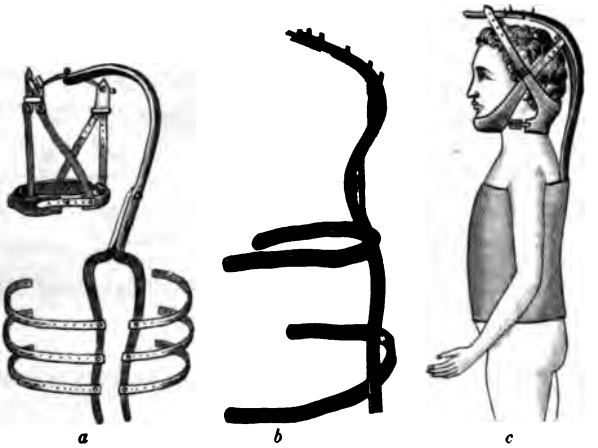
Extension of the Spine.—The following is a brief description of the thods of using extension for the vertebræ: For fractures and tuber- ır inflammation of the vertebræ, Glisson's leather sling with a metal

11.—Permanent extension by weight by means of Glisson's sling for cases of spondylitis.

(Fig. 241) is employed, or Falkson's chin-neck sling of emplastrum sæ (Fig. 242). E. Fischer's suggestion is excellent: A four-cor- l piece of cloth is provided with openings for the face and neck; hen padded in the region of the chin and back of the neck, and our corners of the cloth are brought together over the top of the



12.—Falkson's z for the chin back of the :. made of ce- a plaster and for extension he vertebral mn.



a b c

Fig. 243.—Fixation and extension of the cervical vertebræ for spondylitis cervicalis and dorsalis by means of the jury-mast.

and connected with the cord used for exerting the traction. ter extension is furnished by the weight of the body—i. e., the of the bed is raised, or extension is applied to the legs.

In cases of tubercular inflammation, for example, of the cervical vertebræ, the latter may be fixed and extended by means of the jury-mast corset (Sayre, Figs. 243, 244). For extension of the lumbar and dorsal vertebræ it is best to use the weight of the patient's body by placing him either in a Rauchfuss hammock (Fig. 245) or in a Barwell's sling. The methods of applying these different dressings will be described in the Regional Surgery.

Fig. 244.—Felt corset with jury-mast for fixation of the head in spondylitis cervicalis.

The Amount of Force to be used in Extension.—The amount of traction which may be employed in the different extension appliances varies with the age of the patient and the nature of the disease or injury. For fractures of the femur and hip-joint inflammations in small children, one to two to three kilogrammes are used; for children from ten to twelve years old, somewhat more; while in adults ten to fifteen kilogrammes may be needed.

Extension by Splints.—Extension by splints is much less used now than was formerly the case. Reference will be made in the text-book on Regional Surgery to the splints used for extension purposes, especially under the treatment of injuries and diseases of the hip and lower extremities. Numerous portative extension splints have been devised of late (see Regional Surgery, Injuries and Diseases of the Lower Extremities). For a description of portative splints, see The Treatment of Fractures.

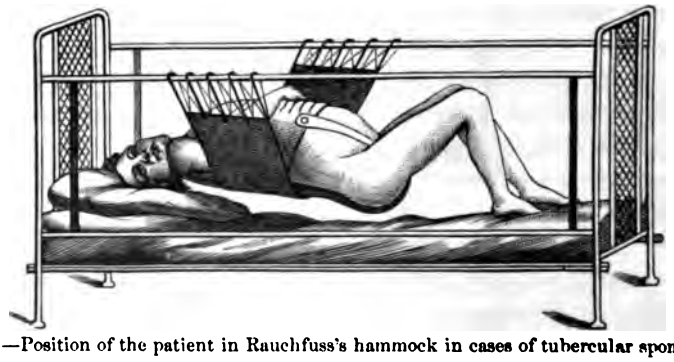


Fig. 245.—Position of the patient in Rauchfuss's hammock in cases of tubercular spondylitis.

THIRD SECTION.

SURGICAL PATHOLOGY AND THERAPY.

CHAPTER I.

INFLAMMATION AND INJURIES.

he phenomena of inflammation.—The histological changes which take place in inflammation.—Causes of inflammation.—Symptoms of inflammation.—Terminations.—Diagnosis.—Treatment.—Morphology and significance of micro-organisms (microbes).—Injuries in general.—The histological changes which occur in the healing of a wound.—The reaction following wounds and inflammations.—Fever.—Shock.—Delirium tremens.—Delirium nervosum.—Disturbances which may arise during the healing of a wound.—Infection of wounds.—Inflammation.—Suppuration of the wound.—Lymphangitis.—Arteritis.—Phlebitis.—Cellulitis.—Erysipelas.—Wound diphtheria (hospital gangrene).—Tetanus.—Septicæmia.—Pyæmia.—Infection by cadaveric poison.—Other kinds of infection.—(Anthrax; symptomatic anthrax.—Glanders.—Hoof and mouth disease.—Hydrophobia.)—Poisoning by insects, snakes, etc.—Curare poisoning.—Appendix: Chronic microbic diseases.—Tuberculosis.—Syphilis.—Leprosy.—Actinomycosis.

§ 56. **Inflammation.**—The physicians of antiquity recognised the four cardinal symptoms of inflammation: Redness (rubor), heat (calor), swelling (tumour), and pain (dolor). But these outward manifestations do not throw light upon the source and essence of inflammation. The question, where the origin of the process is to be found, has always been a subject of discussion, and the principal part in the production of inflammation has been ascribed in turn to the blood, to the tissues, to the blood-vessels, and to the nerves. Numberless experiments have been performed and the most diverse theories have been advanced to account for the phenomena of inflammation. Virchow founded the *cellular-pathology theory*, according to which an "inflammatory irritation" leads to definite changes in the cells. Cohnheim ascribed it to a probable molecular change in the walls of the vessels, while Recklinghausen and Thoma laid stress upon the vasomotor nerves, and particularly upon their centres located in the inflamed region. Of the various inflammatory irritants or causes of inflammation, micro-organ-

isms and the products of their metabolism should be looked upon as the most important.

Changes in the Circulation in an Inflamed District.—In order to understand the nature of inflammation, it is best first to study what takes place in the circulatory system. Cohnheim has shown how these processes may be watched under the microscope. The intestine of an etherised or curarised frog is drawn out through an opening made in the side of the abdominal wall, and the mesentery is spread out on a slide beneath a microscope. In this way the mesentery, with its vessels, is subjected to the influence of the air and the irritating substances in it, particularly the micro-organisms. After a short interval an inflammation begins, all the various manifestations of which can be observed from beginning to end, and all the more exactly if the preparation is protected from all bruising, drying, or soiling, etc. The webbing between the toes or the tongue of the frog can be used in the same manner; the tongue is drawn out and fastened with insect pins to a cork rim around a slide, and then by cauterising or scratching the papillæ an inflammation can be produced and the various phenomena studied.

FIG. 246.—Inflamed mesentery of a frog: *V*, vein; *A*, small artery and capillaries. The vessels contain white blood-corpuscles on their inner walls, some being in the process of emigration; the surrounding tissues contain numerous leucocytes which have already emigrated from the vessels.

There is first seen a dilatation of the exposed vessels of the mesentery, if that is employed, beginning in the arteries and extending to the veins, and to a less extent involving the capillaries. Simultaneously with the dilatation of the vessels the blood stream begins to flow more rapidly, and this is followed sooner or later, in from half an hour to an hour, by a marked slowing of the current. As a result of this slowing the separate corpuscles can be distinguished in the veins and capillaries, and even in the arteries; and they will be found to accumulate, especially in the veins and capillaries. In the veins, particularly, there will be large numbers of colourless blood-corpuscles in the peripheral portion of the current, and occasionally they will stick to the inner walls of the veins (peripheral stasis of the

white corpuscles or leucocytes, Fig. 246). The red cells, on the contrary, continue to flow along with diminished rapidity in the centre of the stream. Presently, following the peripheral stasis of the white cells, there will be observed a new phenomenon: a point will be seen to project from the external contour of some vein or capillary, and then gradually become larger and more and more prominent (Fig. 247, *a*); and finally this bit of protoplasm will only remain attached to the wall of the vessel by one or more processes, and at last becomes entirely separated, which means that a white corpuscle has made its way out of the vein or capillary (Fig. 247, *b*). Six or eight hours later this process has continued to such an extent that the veins and capillaries are surrounded by these migrated white cells. In addition to these cells, which are usually polynuclear, there will be found small round mononuclear cells (lymphocytes), which, according to Grawitz and Ribbert, are to be regarded as derived from the fixed connective tissue cells, though Baumgarten claims that they are likewise white corpuscles which have migrated from the vessels of the same region (leucocytes). According to Baumgarten, the small mononucleated lymphocyte form of leucocyte is the predominant element in chronic inflammations. Waller was the first (1846) to note the migration of the leucocytes from the interior of the vessels, but his observations had been entirely forgotten when Cohnheim rediscovered this phenomenon in 1867.

Fig. 247.—Emigration of leucocytes: *a*, Incomplete, *b*, complete emigration (schematic).

Red blood disks also pass through the walls of the capillaries, but not of the veins, for in the capillaries both classes of cells come in contact with the walls, and are not, as in the veins, confined to separate parts of the blood current. The proportion of red cells contained in the exudate varies; some lie here and there on the outer wall of the capillaries, some collect in tiny punctate hæmorrhages, and some are washed away in the stream of transuded serum. No blood-corpuscles migrate through the walls of the arteries.

The time required for a white cell to pass through the wall of a capillary or vein varies, and the same holds true as to the passage

(diapedesis) of a red cell through the wall of a capillary. Sometimes the movement is slow, while at others a few minutes are enough for three, four, or more cells to escape one after the other at the same spot; and immediately thereafter the blood stream, with its corpuscles, flows on normally past the point where they have escaped.

Significance of the Escape of the Leucocytes.—As Leber has demonstrated, the escape of the leucocytes from the vessels is not unregulated, but they obey an attraction towards the place of irritation similar to that observed by Pfeffer, O. Hertwig and Engelmann in vegetable cells and bacteria upon which certain chemical substances exert a peculiar power of attraction (chemotaxis). The substances which act in this manner on bacteria are the salts of potassium, peptones, and especially all nutritive substances; while other substances, such as free acids and alkalies or alcohol, have a repellent power (negative chemotaxis). These facts, which Pfeffer has demonstrated experimentally for the fungi, have a most important bearing upon the subject of inflammation. This power to attract, or chemotaxis, influences or even controls the movements of the leucocytes in the tissues towards the focus of inflammation, also the actual migration of the cells from the vessels and later the formation of new vessels at the same point. The leucocytes are especially attracted by the bacteria and the products of their metabolism, as well as by different chemical substances, such as copper, mercury, croton oil, turpentine oil, etc. According to Bloch, they are attracted chiefly by the easily assimilated albuminous bodies and carbohydrates which are closely allied to the animal tissues. According to Buchner, the protoplasm of bacterial cells contains substances which exert this attraction upon the leucocytes, the so-called bacterial proteins which Nencki studied as early as 1880 in certain kinds of bacteria, from a purely chemical standpoint. These proteins will produce inflammation or suppuration only after they have become separated from the bacterial cell, consequently only after the latter has died or become diseased. Borissow found that chemotaxis was much more active in young animals than in full-grown ones. He could not determine that a particular substance attracted a special variety of leucocyte. The assembling of cells at the seat of inflammation is to be regarded as essentially a protective measure taken by the organism for the purpose of defending itself against external noxious influences. The leucocytes serve, perhaps, to eliminate, to liquefy, and to separate the inflammatory focus from the healthy living tissues (Leber).

Increased Exudation.—Accompanying the migration or extravasation of blood-cells there is an increased transudation of the liquid elements which infiltrate all the surrounding tissues. This increases

the amount of the lymph current until the lymph channels become inadequate for carrying away the transuded liquid, and then results a swelling of the part of the body which is inflamed. Partly as a result of their own power of locomotion, and partly carried along by the transuded fluid, the white blood-corpuscles become distributed through the tissues at ever-increasing distances from the vessels out of which they have wandered. Finally, both the corpuscles and the exudate make their way to the surface of the mesentery, and there the exudate coagulates, forming a so-called false membrane, which is filled with numberless white blood-corpuscles and a few red ones.

Corresponding to the great number of leucocytes which it contains, the inflammatory exudate is very rich in albumen, while the exudate which follows passive congestion is not (Hoppe-Seyler, Lassar). Only in cases of mild inflammation, or in the early stages of others, does the exudate contain a small number of cells.

According to the character of the inflammatory exudate, we distinguish it as serous, fibrinous, croupous, diphtheritic, suppurative, hæmorrhagic, and ichorous.

Proliferation of Connective-tissue Cells in Inflammation.—Not all of the cells which are found in inflamed parts are migrated leucocytes. The fixed connective-tissue cells proliferate by rapid division, and contribute notably to the cellular infiltration of the inflammatory focus.

According to Stricker and Grawitz, the intercellular substance of the tissues undergoes a cellular metamorphosis when inflamed, reverting to its embryonic cellular state. The cells also which have hitherto lain dormant in the stroma (dormant cells, Grawitz) are said to awake to renewed activity. The views which Grawitz has expressed concerning the process of inflammation are of great scientific interest, but they greatly lack the support of observed facts, and have not yet met with general acceptance.

Inflammation from Croton Oil.—The manifestations of inflammation just described can also be produced by irritating the frog's tongue with very dilute croton oil (1.50 of olive oil), by cauterising it with a stick of nitrate of silver, or by applying a ligature to temporarily shut off the blood from the vessels of the tongue. Precisely similar phenomena can be observed in warm-blooded animals—for instance, in the mesentery of a small rabbit. All the gross changes which take place in an inflammation can be produced in a rabbit's ear by painting it with croton oil, cauterising it, applying a ligature, or by subjecting it to heat or cold, as by dipping it in hot water or lightly freezing it with a cooling mixture. An ear which has been subjected for even a few minutes to a temperature of 56° to 60° C. (140° to 147° F.), or −18° to −20° C. (−1° to −4° F.), will inevitably necrose. After a rabbit's

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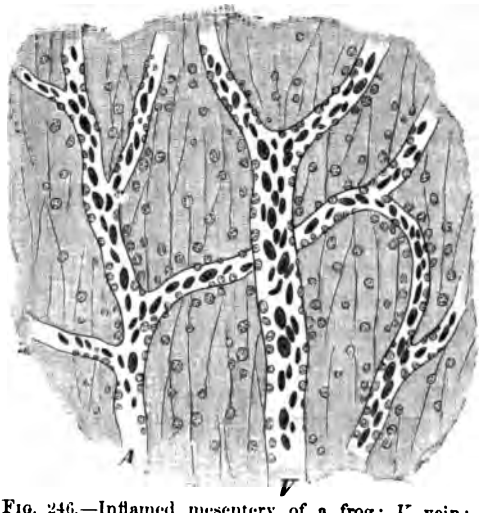

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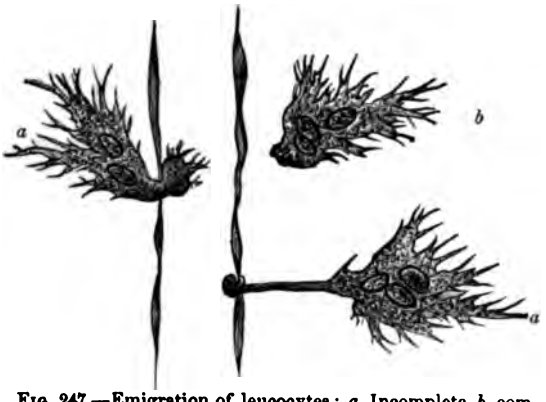

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simple disturbance of circulation following an irritation of the local vasomotor centres produces a peripheral stasis and an emigration of leucocytes. But the latter phenomenon will only last a brief time in those cases in which there is no other influence at work; the vasomotor nerves resume their function, and the peripheral slowing of the current and the escape of the leucocytes cease. If the disturbances in innervation are more marked, and if the emigration is allowed to go on for a longer time, a secondary change in the walls of the vessels takes place. But in these cases the disturbance in the innervation of the vessels is the primary event, and not the alteration in their walls. Thus Recklinghausen seems to be correct in ascribing to the vasomotor nerves, and particularly to their terminal local centres, an important part in the inflammatory process, and especially in the emigration of the leucocytes. Herpes zoster and other diseases resulting from disturbances in innervation go to prove the truth of this theory. Samuel has shown that the inflammatory process becomes more severe when there is vasomotor paralysis. Moreover, the emigration of leucocytes is affected in both a positive and negative way by the above-mentioned chemotaxis. On the other hand, the exudation of the fluid elements of the blood during an inflammation can only be explained by a change in the permeability of the walls of the vessels, located in either the endothelial cells or the cement substance between them.

According, then, to our present knowledge, we must look for an explanation of the phenomena of inflammation (1) in vasomotor changes in the vessels, or, rather, in disturbances within the vasomotor centres in the walls of the vessels; (2) in an increased permeability of these walls; (3) in the positive (attracting) and negative (repelling) chemotaxis of the inflammatory focus, and finally (4) in the reactionary proliferation of the cells in the inflamed tissues. It is an exceedingly difficult matter to give an exhaustive and satisfactory definition of inflammation.

Other Theories of Inflammation.—Before Cohnheim, Recklinghausen, and Thoma had established the above explanation of inflammation, a great variety of theories had been advanced, the most important being the neurohumoral (Cullen, Henle) and the cellular (Virchow). According to the former, the nature of inflammation or the disturbances in the circulation are explained either by the contraction or dilatation of the afferent arteries, produced reflexly through stimulation of the sensory nerves. We have seen that nervous influences really do play an active part in the process of inflammation.

Virchow's cellular theory of inflammation is based upon the changes in the life of the cells brought about by the primary causes of inflammation. Virchow regarded the cells of the tissues as the essential elements in the inflammatory process. As a result of the inflammatory irritation they we

ear has recovered from the effects of croton oil, it gains, according to Samuel, a kind of immunity as regards this drug—i. e., it reacts to a subsequent application of the oil much less violently than an ear which has not been so treated.

The phenomena thus described—viz., the simple congestive hyperæmia, the extravasation of the corpuscular elements from the capillaries and veins, the increased exudation terminating in stasis and later in death of tissue, and also the proliferation of the fixed connective-tissue cells—form a group of symptoms which we are accustomed to designate by the name of inflammation.

Cause of Inflammation.—Cohnheim ascribed the cause of all these phenomena and the essence of inflammation to molecular changes in the walls of the vessels. According to him, these molecular changes increase the adhesiveness, and consequently the friction, between the blood and the walls; hence the slowing of the stream. Exactly what kind of a change is produced in the vessel walls in inflammation is not clearly understood; it cannot be detected with the microscope, and we can only say that the walls become more pervious, enough so to occasion the increase in exudation notwithstanding the diminution of the blood pressure which takes place especially in the capillaries. Winiwarter has shown that a colloid liquid, such as a solution of glue, can pass through the inflamed walls of blood-vessels even when the pressure is subnormal. A rupture, an interruption of continuity in the wall of the vessel, permitting the escape of the leucocytes and of a few red corpuscles, certainly does not take place. Likewise, Arnold's theory that in inflammation the natural stomata between the endothelial cells become enlarged and that new ones form, is, as Cohnheim always maintained, incorrect. Cohnheim's comparison of inflammatory exudation with filtration seems very appropriate. Under normal conditions only a small amount of a thin liquid can pass through the filter of the vessel wall; but when inflammation sets in the filter becomes coarser and permits not only denser solutions to pass through, but also formed elements, the blood-corpuscles. The change produced in the vessel wall by inflammation is, according to Cohnheim, probably chemical.

But all the manifestations of inflammation cannot be explained by the condition of the vessel walls, which Cohnheim thought was sufficient. The investigations recently made by Recklinghausen, Arnold, and others go to show that Cohnheim's theory needs certain limitations in view of the fact that a distinction must be made between the exudation of fluid constituents of the blood and the emigration of white corpuscles. Thoma's researches have shown that a primary alteration in the walls of the vessels is not always the cause of the emigration. I

simple disturbance of circulation following an irritation of the local vasomotor centres produces a peripheral stasis and an emigration of leucocytes. But the latter phenomenon will only last a brief time in those cases in which there is no other influence at work; the vasomotor nerves resume their function, and the peripheral slowing of the current and the escape of the leucocytes cease. If the disturbances in innervation are more marked, and if the emigration is allowed to go on for a longer time, a secondary change in the walls of the vessels takes place. But in these cases the disturbance in the innervation of the vessels is the primary event, and not the alteration in their walls. Thus Recklinghausen seems to be correct in ascribing to the vasomotor nerves, and particularly to their terminal local centres, an important part in the inflammatory process, and especially in the emigration of the leucocytes. Herpes zoster and other diseases resulting from disturbances in innervation go to prove the truth of this theory. Samuel has shown that the inflammatory process becomes more severe when there is vasomotor paralysis. Moreover, the emigration of leucocytes is affected in both a positive and negative way by the above-mentioned chemotaxis. On the other hand, the exudation of the fluid elements of the blood during an inflammation can only be explained by a change in the permeability of the walls of the vessels, located in either the endothelial cells or the cement substance between them.

According, then, to our present knowledge, we must look for an explanation of the phenomena of inflammation (1) in vasomotor changes in the vessels, or, rather, in disturbances within the vasomotor centres in the walls of the vessels; (2) in an increased permeability of these walls; (3) in the positive (attracting) and negative (repelling) chemotaxis of the inflammatory focus, and finally (4) in the reactionary proliferation of the cells in the inflamed tissues. It is an exceedingly difficult matter to give an exhaustive and satisfactory definition of inflammation.

Other Theories of Inflammation.—Before Cohnheim, Recklinghausen, and Thoma had established the above explanation of inflammation, a great variety of theories had been advanced, the most important being the neurohumoral (Cullen, Henle) and the cellular (Virchow). According to the former, the nature of inflammation or the disturbances in the circulation are explained either by the contraction or dilatation of the afferent arteries, produced reflexly through stimulation of the sensory nerves. We have seen that nervous influences really do play an active part in the process of inflammation.

Virchow's cellular theory of inflammation is based upon the changes in the life of the cells brought about by the primary causes of inflammation. Virchow regarded the cells of the tissues as the essential elements in the inflammatory process. As a result of the inflammatory irritation they were

caused to swell and proliferate and form pus-corpuscles. These altered cells are supposed by Virchow to exercise a kind of attractive power for the contents of the vessels, producing increased exudation.

Samuel thinks that inflammation is due to a changed relationship of the blood, the walls of the vessels, and the tissues to each other. Recklinghausen agrees with him in general.

Landerer thinks that the inflammatory changes in the circulation depend upon a disturbance of the normal balance between the blood pressure and the tension of the tissues, caused by a change in the elastic properties of the tissues and the walls of the vessels. This change in elasticity, he is inclined to believe, is the primary factor, though he admits that the walls of the vessels may become primarily diseased.

No one of these theories can by itself explain the nature of inflammation, especially if that theory is based upon only a single manifestation of the inflammatory process and attempts to solve the problem from this standpoint alone. Consequently, it is evident why Cohnheim's attempt to explain inflammation by a change in the walls of the vessels is to-day regarded as inadequate. No value can be attached to any theory which does not include a correct explanation of the changes produced under the stimulus of inflammation in both the solid and fluid elements of the tissues (cells, nerves, and walls of the vessels), and does not consider these in their causal relationship to one another.

§ 57. **Causes of Inflammation.**—The *causes of inflammation* are very numerous. Any influence which produces a change in the walls of the vessels in any particular part of the body, in the manner above described, may give rise to inflammation. We recognise principally the following classes of inflammation which differ in point of etiology:

1. Inflammation from mechanical causes (every kind of traumatism).

2. Inflammation following the action of extremes of temperature (thermal inflammation; burning, freezing).

3. Inflammation due to chemical causes (toxic materials and bacteria).

Under the heading of toxic inflammations belong not only those which are produced by the action of some particular chemical such as mercury, sulphuric acid, etc., but it includes all inflammations caused by the absorption of chemically changed, decomposed, or putrid substances of a gaseous or liquid nature. Inflammations following the stings of insects, such as bees, and those from the bites of serpents, all come within the class of toxic inflammations. Advancing a step further, we come to the infectious inflammations, or those which are produced by the ingress of a low order of organism or fungi—for example, after an injury to the tissues from some traumatism.

Significance of Micro-organisms.—*Micro-organisms*, especially the fungi schizomycetes or bacteria, are the worst enemies of the surgeon,

interfering with the normal healing process of a wound and causing the secondary wound diseases. Hallier, Pasteur, Billroth, Klebs, Eberth, and particularly Robert Koch and his followers, have made great advances in the study of micro-organisms. The honour of having established the etiology of parasitic infectious diseases by means of new methods of investigation belongs chiefly to Robert Koch. At the time when Lister established his antiseptic and aseptic methods of operating on the principle that all infection was due to bacteria, which, though not then proved, nevertheless seemed probable, surgery made the greatest advance in its history. Every inflammatory process in a wound, especially all suppuration, is due principally to the presence of micro-organisms, while the injury itself plays only a subordinate part.

Causes of Acute Suppurative Inflammation—Significance of Bacteria.—The investigations of Ogston, Strauss, etc., prove that chemical irritants, no matter of what kind, do not excite suppurative inflammation, but that the latter can only be caused by micro-organisms. These authorities performed their experiments with the most rigid antiseptic precautions. Strauss, for example, to prevent accidental infection from the wound, made an eschar over the selected area of skin with the Paquelin, then through this made his incision with a red-hot knife, and introduced the long tip of a glass tube containing the sterilised fluid into the subcutaneous cellular tissue, the upper end of the tube meanwhile being closed with a cotton plug. The glass tip was then broken off beneath the skin, and the fluid was forced out of the tube and under the skin by blowing with the mouth over the cotton plug. After taking away the tube the injured area of skin was again cauterised. After the introduction in this manner of such chemical irritants as sulphuric acid, turpentine, croton oil, mercury, etc., only a serous, sero-fibrinous, or fibrino-diphtheritic inflammation resulted, but never acute suppuration. If acute suppuration did occur, it was always possible to demonstrate the presence of micro-organisms. These authorities experimented on rabbits, in which, to be sure, a suppurative inflammation is seldom caused by chemical irritation.

But it has recently been proved that these statements are incorrect. Orthmann, Grawitz, and De Barry have demonstrated that sterilised chemical substances, such as nitrate of silver, oil of turpentine, liq. ammonii caustici, digitoxin, etc., can produce acute suppuration in the subcutaneous tissue; and according to Scheuerlen and Grawitz, sterilised cultures of various micro-organisms—in other words, products of bacterial metabolism, such as putrescin, cadaverin, penthamethylendiamin, etc.—act in the same way. A similar conclusion has been reached by Krynski, who experimented on dogs and rabbits with the greatest care, partly by Strauss's and partly by Councilman's methods, using germ-free (aseptic) chemical substances, the microbes which cause suppuration and the products of their metabolism. Krynski asserts, in opposition to Strauss and others, but agreeing with Brewing and Dubler, that oil of turpentine or mercury produces in dogs and rabbits a suppuration which is free from bacteria. A one-to-five-per-cent. solution of nitrate of silver excites the formation of pus in dogs, but only an inflammatory œdema in rabbits. Croton oil, bromine, mineral acids (hydrochloric, sulphuric, nitric, and

chromic), organic acids (acetic, carbolic, lactic, etc.) do not cause pus. In dogs it is produced by creolin and petroleum. Clean, mechanically acting agents, such as glass splinters, do not excite pus formation. The bacteria of suppuration (the staphylococci and streptococci), according to Krynski, will only excite the formation of pus in tissues which have become pathologically changed, and they will not develop in healthy tissues, but are destroyed, while the *Bacillus pyogenes fœtidus* will excite suppuration even in perfectly healthy tissue. Krynski maintains that the *Pneumococcus Friedländeri* and the *Micrococcus prodigiosus* are not pyogenic; but Grawitz and De Barry have established the latter's pyogenic character in the case of dogs, cats, rabbits, and rats. Sterilised cultures of the staphylococci and streptococci, or the sterilised solutions of the products of their metabolism, will produce pus, while sterilised cultures of the prodigiosus and decomposition extracts have no such power. Although there can be no doubt as to the possibility of exciting suppuration in the subcutaneous tissue of animals by the experimental introduction of germ-free chemical substances, yet it is just as true that suppuration in man under ordinary circumstances is caused by the presence and activity of micro-organisms, usually of a specific variety—viz., pyogenic cocci.

Immunity against Virulent Staphylococci.—The investigations of Roux, Kronacher, and others are of great interest as regards the acquirement of immunity against virulent staphylococci. By the inoculation of sterilised cultures of the *Staphylococcus pyogenes aureus* white mice can be made unsusceptible to cultures containing virulent cocci.

Bouchard, Gley, and others have shown that the injection of the soluble products of certain micro-organisms such as the *Bacillus pyocyaneus* has an antiphlogistic effect from paralysis of the vasodilator nerves, which prevents dilatation of the vessels and emigration of the leucocytes.

Leber's Phlogosin—Buchner's Bacterial Protein.—Leber's investigations are extremely interesting. He showed that the micro-organisms, in virtue of the diffusible products of their metabolism, can excite an inflammatory reaction through chemotaxis at a distant part of the body, and from liquids containing staphylococci he isolated a crystallisable body, phlogosin, capable of producing intense inflammatory and necrotic processes. Buchner demonstrated that the protoplasmic contents of the bacterial cells, the so-called bacterial protein, has a similar power of exciting inflammation and suppuration when separated from the bacterial cells—in other words, when these die or become diseased. Buchner has so far isolated this protein from several kinds of bacteria, and proved its pyogenic action.

Inflammatory Leucocytosis.—After invasion of the blood-vessels with the fungi of suppuration there is an increase in the number of leucocytes in the blood (inflammatory leucocytosis), originating in the spleen, the lymph glands, and bone marrow. According to Limbeck, this is not so much a new formation of leucocytes as a result of the flushing out of the above organs. This inflammatory leucocytosis has an intimate connection with the exudation accompanying inflammation, and with the peptonuria (Leber, Hofmeister, Maixner, etc.).

As to the influence of micro-organisms upon the production of wound diseases, etc., we shall see later (§ 66) that each separate wound

disease is caused by a particular and clearly distinguishable micro-organism. A short review of the morphology and general significance of these will be found in § 59.

§ 58. **Symptoms, Diagnosis, and Treatment of Inflammation.**—The symptoms of inflammation—redness, swelling, increased warmth, and pain—are easily explained by the disturbances of circulation which have been described. The redness and increased warmth are due to the distention of the blood-vessels; the swelling is likewise the result of this, and particularly of the exudation. The pain is caused by the pressure of the over-filled vessels and of the exuded fluid upon the sensory nerves. A fifth symptom is the disturbance of function, and is produced by the change in the circulation and the pressure of the exuded fluid upon the motor nerves, and upon those governing secretion, or upon the cells themselves. The separate symptoms naturally vary considerably in intensity, depending upon the severity of the inflammation, and particularly upon its location.

The pain in inflammation depends upon the richness of the sensory nerve supply in the inflamed part, and upon the amount of the exudate, or rather of the pressure which the exudate produces on the sensory nerves. Furthermore, the amount of expansion that the inflamed part is capable of is an important factor. For all these reasons, an acute inflammation located under the fascia, or in the tips of the fingers, under the nails, is particularly painful, while one involving mucous membrane is much less so.

The increased warmth is the result of an increased amount of blood. As Cohnheim has shown, nearly double the normal amount of blood flows through a dog's paw when inflamed. There is an increased amount of warmth brought to the part, but the diminished rapidity of the current causes an increase in the loss of heat by radiation. There has been an erroneous belief that the inflammatory focus was in itself productive of heat, and that the temperature at this point was higher than the general body temperature. But ordinarily it is certain that the temperature of the inflamed spot never exceeds that of the blood, and generally is not as high. Hunter's law still holds true to this day —viz., that the local temperature of an inflamed part cannot rise above that at the source of the circulation, the heart. The redness is usually dependent upon the richness in blood supply of the inflamed tissue. The swelling or inflammatory tumefaction resulting from the exudation which takes place varies, of course, with the anatomical structure of the inflamed region. In general, the exudation takes place in the same way, but it may manifest itself in many different ways, depending upon whether it occurs in firm tissues like bone or cartilage, or

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in wide-meshed connective tissue, or in a glandular organ, or in a cavity, such as the pleural cavity. The inflammatory exudate accumulates where it finds the least resistance.

As regards the location of the inflammation, we distinguish between a superficial and a deep or parenchymatous inflammation in the interior of an organ. To the superficial inflammations belong those situated in the superficial portions of the body, in the mucous membranes, or the surfaces of the great serous cavities. In a superficial inflammation the inflammatory exudate appears superficially, and forms an exudate in the narrow sense, while in a parenchymatous inflammation the exudate is spread out in the tissue in question in the form of a so-called infiltration. For distinguishing the location of the parenchymatous inflammations more exactly—as, for example, those which occur in the glands or muscles—a distinction is made between a parenchymatous inflammation in its narrow sense and an interstitial inflammation, according as the inflammatory process affects more the gland cells, such as those making up the parenchyma of the liver, or the connective-tissue stroma.

The Varying Constitution of the Inflammatory Exudate.—The composition of the exudate is of the greatest importance in determining the character of the inflammation. If the latter belongs to the lower grades of the process, or if, in other words, there is but a slight change in the walls of the vessels, the exudate is serous—that is, there is only a small amount of albumen and formed elements (blood-corpuscles) contained in it. On the other hand, we speak of a fibrinous or croupous inflammation when the exudate is rich in spontaneously coagulating albumen —i. e., in white blood-corpuscles. In a fibrinous inflammation the diseased part, such as, for instance, the serous membrane or the inner surface of a joint capsule, becomes covered with a more or less thick layer of soft fibrin, which gives it sometimes a smooth and sometimes a shaggy appearance. The microscopic examination of such a fibrinous pseudo-membrane reveals the presence of an immense number of white blood-corpuscles scattered among threads of fibrin and granular matter. This same croupous or fibrinous covering is found on the surfaces of mucous membranes. According to Neumann, Grawitz, and others, the fibrinous covering on the surface of serous membranes is the result of a fibrinoid degeneration of the connective tissue, but Ziegle and others regard it as the fibrin formed in the exudate. In tubercular inflammation there is a marked hyaline degeneration of the connective tissue. Between the two main types of serous and fibrinous inflammations there are, of course, a number of intermediate forms which are designated as sero-fibrinous exudates.

Suppurative Exudate.—The third kind of exudate is the suppurative or purulent, consisting of a thick, milky, or cream-like, non-coagulable fluid, generally without odour, and briefly designated by the name of pus. Microscopically, this is a colourless fluid containing a vast quantity of cells, "pus cells," and a few red blood-corpuscles. According to Grawitz, the suppurative inflammation is only a more advanced grade of inflammation, while Weigert, on the other hand, maintains that it represents qualitatively a particular kind. Stricker and Recklinghausen think that suppuration is not exclusively a melting-down process of the tissues without coagulation, produced by means of emigrated leucocytes, but rather that a proliferation of the fixed connective-tissue elements also plays an important part. There is always an enlargement and multiplication of the fixed connective-tissue cells in the vicinity of the suppurative focus. By the proliferation of the fixed cells a large number of young cells are formed which correspond in appearance to the mononuclear white blood-corpuscles.

Pus is a product composed of emigrated leucocytes and the varied offspring of the connective-tissue cells. Every suppurative inflammation is to be considered as a severe inflammation, and, as we have indicated, it is in the main of an infectious nature—that is, it is the result of an infection by bacteria. But we have seen that sometimes even germ-free chemical substances may produce suppuration (Grawitz, De Barry, Krynski, etc.).

Between the extreme types of purulent and fibrinous inflammation there are also many intermediate gradations of the process which are known as fibrino-purulent inflammations. If the suppurative process is sharply defined in the tissues, there results what is called an abscess; but if the process is more diffuse, it is spoken of as suppurative infiltration. An abscess—i. e., a cavity filled with pus—results from a suppurative infiltration which liquefies and dissolves the affected tissues. A loss of substance in the superficial portions of the body, accompanied by the formation of pus and breaking down of the granulation tissue, constitutes an ulcer. A collection of pus in a cavity is called a purulent effusion, while a purulent secretion from a mucous membrane is called a purulent catarrh.

Hæmorrhagic Exudate.—The fourth kind of exudate is the hæmorrhagic—i. e., the serous, fibrinous, or purulent exudate contains such an amount of red blood-corpuscles that it becomes red in colour. The hæmorrhagic exudate is a symptom of serious alterations in the walls of the capillaries, such as takes place in certain constitutional diseases, or as a result of a systemic infection through bacteria.

Ichorous Exudate.—The decomposed, foul-smelling exudate accompanying putrefaction is designated as ichorous or putrid. It has a grey or greyish-green, brown, or dirty yellow colour.

Croupous or Diphtheritic Inflammation.—The so-called croupous or diphtheritic inflammation, or the croupous or diphtheritic exudate, is the result of the combination of an inflammatory process with another of a different nature. Croupous inflammation of a mucous membrane is characterised by the formation of a skin-like, fibrinous exudate (croupous membrane) clinging to its surface and taking the place of the original epithelial covering which has perished. This croupous membrane consists of a network of fibrin fibres containing leucocytes and the remains of the epithelium.* In diphtheria the death of tissue extends deeper, and the process is a combination of necrosis and fibrinous inflammation. The affected portion of the mucous membrane is changed into a peculiar greyish-white, tough mass, which comes away in membrane-like layers (diphtheritic pseudo-membrane), and produces corresponding losses of substance (diphtheritic ulcers). The tissues destroyed by the inflammatory process coagulate in flaky or stringy masses, which signifies serious structural changes involving the blood-vessels and surrounding tissue, with here and there stasis and thrombosis. Cohnheim and Weigert have given to this form of localised tissue death the name of coagulation necrosis (Neumann's fibrinoid degeneration). Weigert's investigations show that coagulation necrosis is a death by coagulation of the tissue or cells in a necrotic area through which a small amount of lymph flows. The lymph, with its fibrinogen, penetrates the cells and coagulates with the fibrino-plastin within the cells. Coagulation necrosis is a frequent accompaniment of inflammatory processes, of embolic infarcts, and of the so-called waxy degeneration of muscles.

Extension of an Inflammation.—The inflammatory process spreads by infiltration of the connective-tissue spaces, the muscular sheaths, and the vascular channels with the inflammatory exudate—in other words, from a circumscribed spot of suppuration (abscess) there may develop a spreading cellulitis. The inflammation also spreads through the lymph spaces, the main lymphatics, and the blood-vessels. When the exciting cause of the inflammation gets into the circulatory system, the original local disturbance becomes a general systemic disease involving the whole organism. The poison—so to designate briefly the noxious element—passes through the lymph channels to the nearest lymphatic glands, exciting there also inflammation, and finally suppuration. These diseased glands then become a fresh source of inflammation, which in this manner spreads farther and farther through

the body and progressively affects more of its organs. Such a metastatic inflammatory and suppurative process will be again referred to under the heading of pyæmia, by which we mean a poisoning of the blood by the microbes of suppuration and the products of their metabolism. By the spreading of the micro-organisms and the products of their metabolism throughout the circulation, and the production of circumscribed foci of inflammation in different organs, a general systemic infection accompanied by fever results (see § 62, Fever). We shall learn later how prominently the fungi are concerned in the extension of the inflammation and in the occurrence of the systemic infection. Clinical observations and experiments on animals seem to show that local metastatic foci of suppuration are particularly liable to occur when there exists a general weakness or impairment of vitality of the whole organism (Rinne). The soil for the lodgment of the micro-organisms is made ready for them in advance by the products of their metabolism which get into the circulating blood.

Duration of an Inflammation.—According as the inflammation lasts a shorter or longer time it is spoken of as acute or chronic. The manifestations of an acute inflammation have been sufficiently described above. The acute inflammation often becomes a chronic one, or the latter begins from the first as such. The transition or intermediate types between an acute and chronic inflammation are known as subacute inflammations. Tubercular and syphilitic inflammations are the most important forms of the chronic class. The true type of chronic inflammation is the productive or adhesive inflammation, which leads to new formation of tissue, to adhesions and thickenings of every description, depending upon the anatomical structure of the affected organ, such as a joint, bone, periosteum, or connective tissue. We shall describe in their proper place the special symptoms of inflammations involving the different organs.

Origin of the Pus-corpuscles.—The so-called pus-corpuscles which are found in the inflammatory effusion are made up, in part at least, of the white blood-corpuscles which have wandered out from the interior of the vessels. Whether all the pus-corpuscles are emigrated blood-cells, or whether pus-cells may originate otherwise—as, for instance, from the fixed tissue cells—or whether pus-cells may multiply by fission or division, are all questions to which various answers have been given. Some have considered it impossible that the enormous number of pus-corpuscles found in a large inflammatory process, like a phlegmon or a large granulating wound, should all be derived from the blood. Cohnheim was right in directing attention to the fact that the veins and capillaries contain comparatively large numbers of white blood-corpuscles, and that the number of these white cells is much increased during inflammatory diseases. The white blood-corpuscles which go to form pus-cells are constantly replaced by an increased activity of the

spleen and lymphatic glands. Böttcher, Stricker and his followers, Recklinghausen, Grawitz, and others differ from Cohnheim in his view that the blood is the sole source of the pus-cells, and affirm that the latter originate also from the fixed tissue cells. These authors believe that the cellular elements of pus consist partly of emigrated leucocytes and partly of the offspring of the fixed connective-tissue cells. Grawitz affirms that the stroma or fibrous portion of the tissues takes on a cellular change and becomes a third source of the pus-corpuscles. Recklinghausen has demonstrated that pus-cells, if kept in a warm and moist medium while being examined, will change their form and go through the same amœboid movements as the white blood-cells.

Number of Pus-cells in Pus.—Chelchowski determined the number of pus-corpuscles by means of Mallassey-Verick's apparatus in twenty different cases of suppuration. For diluting the pus, he employed a weak solution of common salt or Toison's fluid (methylviolet). The number of pus-cells in one cubic millimetre of pus, according to Chelchowski, varied between four hundred thousand and one million six hundred thousand. The exudate contained from ten to fifteen times more leucocytes than the transudate.* The suppurative character of a fluid, drawn off by aspiration, can only be recognised macroscopically when it contains at least from forty to sixty thousand pus-cells to the cubic millimetre, and consequently it is very possible for a comparatively large amount of pus to be present in a fluid without its being noticed.

Composition of Pus.—Pus consists of the above-mentioned cellular elements, which are called pus-corpuscles, and, in addition, of pus serum. If pus is allowed to stand for a time in a test tube, it separates into two layers, the upper bright yellow layer being the pus serum, and the lower forming a thick deposit made up principally of pus-corpuscles. The pus serum corresponds to the plasma of the blood which is its source, but often differs from it chemically very materially. There are ten to sixteen per cent. of solid elements in pus, and five to six per cent. of ash. The gases consist of nitrogen and carbonic acid; ordinarily there is no oxygen or hydrogen. There is generally a somewhat greater amount of sodium and potassium than in blood serum. The albuminous substances in pus consist chiefly of paraglobulin, albuminate of potassium, serum albumen, myosin, leucin, and tyrosin. The formed constituents, in addition to the pus-corpuscles, include micro-organisms, and often red blood-cells, fibrin, fat droplets, fat and cholesterin crystals, particles of necrotic tissue, etc. Sterilised pus serum has nearly the same toxic action as the sterilised products of the *Staphylococcus aureus* and *albus* (page 328); repeated injections give rise to chronic marasmus (Nasmoki). Pus which contains fungi usually does not coagulate, although large numbers of leucocytes may be present. This is due to the fact that there is no fibrinogen in the pus, or rather that the micro-organisms change the fibrinogen in the exuded plasma into peptone.

Growth of Bacteria in Germ-free Pus.—According to Eichel, germ-free pus contains a substance which is deleterious for many kinds of bacteria, and small quantities of the *Staphylococcus pyogenes aureus* and the anthrax bacillus will perish after about five days, but the streptococci are not harmed.

* In the sense of a passive effusion, as in cardiac dropsy.

By the addition of putrefactive bacteria or the products of their metabolism this deleterious property is increased. The reaction of pus which has recently been taken from the body is alkaline, but it becomes acid after long exposure to the air.

Coloured Pus.—Green or blue pus is sometimes found instead of the usual creamy, more or less yellow-coloured variety. This discolouration is usually brought about by the presence of the bacillus pyocyaneus (see pages 330, 331). O. Grube and Ferchmin have seen fourteen cases of bright red pus. The cinnabar colour is due to a specific bacillus (see page 331). Orange-coloured pus occurs as the result of the admixture with crystals of hæmatoidin.

Outcome of an Inflammation.—In considering the outcome of an inflammation, the secondary conditions that follow must be distinguished from the purely local processes at the seat of the inflammation. As regards the system at large, the main purpose of inflammation is to do away with the causes which give rise to the inflammation, accomplishing this by increased metabolism, rapidity of circulation, and transudation. The processes which take place in an inflammation combat its causes in an efficient way, and try to make reparation for the damaging effects that it produces (Leber, Arnold). In many cases the inflammation is not capable of removing the causation of the disease. Death may occur at any stage of the inflammation, but especially when the inflammatory process is at its height, as a result of a general systemic infection with fever, due to the primary local inflammation. We shall learn in § 62 about the significance of fever and its dangers for the organism. From a prognostic standpoint, the location of the inflammation is of the greatest importance. A subcutaneous abscess is by no means as dangerous to life as a very minute collection of pus in the bones of the skull, the meninges, or in the brain, the medulla oblongata, etc. The age and constitution of the patient are likewise important factors.

If we take a purely local view of the outcome of an inflammation, the worst that can occur is gangrene or necrosis—i. e., death of the affected tissues. In its various gradations this is a very frequent result of an inflammation, and is due either to complete stasis in the vessels, followed by coagulation of the blood which they contain, or to pressure of the exudate on the surrounding tissue. Furthermore, in a localised death of tissue, constitutional conditions, such as diabetes or old age, play a very important part. We shall return to the discussion of localised death of tissue (gangrene, necrosis, or mortification) in another chapter. It will only be stated now, that in general the extent of the inflammatory necrosis varies greatly, depending upon the intensity and extent of the inflammation. We shall see that the influence of micro-organisms, such as single groups of bacteria, is a prominent

factor in the production of gangrene. The capability on the part of the tissues, and especially of the vessels, of withstanding gangrene varies greatly with the portion of the body which is affected and with the individual. The most favourable outcome of an inflammation is a complete *restitutio ad integrum*—a perfect restoration to the original condition—which of course is most frequently observed after an inflammation of a mild type in which the exudate has been scanty and chiefly serous. The disappearance of the phenomena of inflammation begins as soon as the circulating blood has restored the walls of the blood-vessels to their normal condition, and when this has taken place the exudation ceases. The fluid portion of the exudate is absorbed by the lymph vessels, likewise the white blood-corpuscles and fibrin, after they have in part undergone a fatty degeneration. The red blood-cells lose their colouring matter, and gradually become disintegrated. The fixed tissue cells which have been damaged by the inflammatory irritation recover after the restoration of their normal nutrition, and by degrees a complete restitution takes place. Sometimes, however, after absorption of the fluid the formed or solid elements of the exudate remain behind as a light yellow, caseous mass, which, by a reactive inflammation, becomes encapsulated as a cheesy nodule, like a foreign body. Under such conditions complete absorption often does not occur, and finally a deposition of salts of lime takes place, forming a firm, calcareous concretion.

If the inflammatory process is more severe, and if there is localised death of tissue, the absorption of the exudate and the necrotic soft parts takes place in a similar manner—i. e., by absorption of the fluid and fatty emulsion of the solid elements. Small portions and granules of tissue, in case they are not taken up by the lymph channels, are seized by the cells which have wandered out of the vessels, and which in this way become granular cells. If, as the result of an inflammation, a portion of bone has become necrotic, the dead piece of bone or sequestrum is separated from the living bone by a suppurating line of demarcation (see § 106). The pus formed during an inflammatory process near the surface of the body may break through spontaneously, or be removed artificially by operative measures, such as incision, etc.

There is the danger in all infectious inflammations, or those cases of suppuration which are due to micro-organisms, that the inflammation may become the starting-point for a general infection. Therefore, whenever it is possible, operative measures should be undertaken at an early period to provide a way of escape for the exudate, for otherwise the inflammation and suppuration may spread, resulting in an extensive infiltration or phlegmon, which may break through into

an important organ, such as a joint, the cranial cavity, abdominal cavity, etc. Moreover, the micro-organisms that cause the inflammation are scattered about by the lymph- and blood-vessels. It must always be borne in mind that products are constantly being formed in an infectious inflammation which are capable of producing further inflammation in the surrounding parts and in widely separated organs. The bacteria, and the products of metabolism and decomposition which they cause, are here again the causes of the secondary inflammatory processes. As a result, then, of infectious inflammations, bacteria may be deposited in large numbers in different internal organs, causing secondary so-called metastatic abscesses.

Scar Formation.—If a defect or loss of substance results from a severe inflammation with necrosis, this is remedied to a greater or less extent by a new production of connective tissue, which is then called cicatricial tissue. Scar formation is to be looked upon as an inflammatory process which is productive in character. A germinal or granulation tissue, as it is called, develops, consisting only of round cells with a very small amount of intercellular substance; this granulation tissue then gradually changes into fibrous connective tissue, which makes up the cicatrix. I used to believe, as Cohnheim did, that the new-formed connective tissue, the granulation and cicatricial tissue, was chiefly derived from the emigrated leucocytes, which increase in size when the new blood-vessels developed among them and became large, irregular-shaped cells (fibroblasts). But some recent investigations have made me conclude that the leucocytes at the inflammatory focus are unfit for making new connective tissue and healing up the wound, and I am now convinced that they gradually disappear, partly by wandering into the lymphatic vessels and being carried off in the lymph current, and partly by wandering into other localities and disintegrating and being taken up by the fixed cells of the part (Baumgarten, Zahn, Marchand, etc.). Ziegler has also expressed the same view. The newly formed connective tissue, therefore, is in reality produced by a growth of the fixed connective-tissue cells (Baumgarten, Marchand, etc.). Marchand has proposed to designate the leucocytes originating from the blood and lymphatics as exudation cells, in contradistinction to the granulation or true formative cells which are derived from the tissues. The formative cells get their nourishment from the protoplasm of the leucocytes, as I have mentioned above. Sherrington, Ballance, Shattuck, and others maintain that the plasma cells are the ones chiefly concerned in the formation of cicatricial tissue (see also § 61).

Regeneration of the Tissues.—Simultaneously with the formation of the granulation or cicatricial tissue there is a proliferation of the fixed

(specific) cells in the neighbourhood for the purpose of restoring the cells that make up the particular structure. Epithelium gives rise to epithelium; muscle cells form muscular fibres, though in a very limited amount; periosteal and medullary cells make bone, etc. The power of regeneration possessed by the different tissues varies very greatly, as we shall see. The skinning over or covering of a loss of substance in the skin with epidermis is brought about by the cells of the rete Malpighii and sebaceous glands. Reference is made to § 61 for the description of the various phenomena in scar formation and regeneration in the different tissues (microscopic phenomena in the healing of a wound), and to §§ 87 and 88 (Injuries of Soft Parts). For the process of healing of fractures see § 101.

The Healing of a Foreign Body into a Wound.—If the inflammation is caused by the entrance into the tissues of a solid foreign body, the latter may completely heal into the tissues, as we shall often have the opportunity of observing; and this will occur the more readily the more free the body is from dirt, dust, bacteria, products of decomposition, etc. We know that silk sutures, silver wire, bullets, etc., heal up in a wound in this way without giving rise to any reaction. Foreign bodies which have thus become enclosed often change their location later on, and in their wanderings may make their appearance beneath the skin in another portion of the body. Large, soft foreign bodies are completely absorbed in the way described above. I implanted, under antiseptic precautions, large fresh pieces of liver, spleen, lung, and even entire kidneys of rabbits, in the peritoneal cavities of other rabbits, and found that they became absorbed without producing peritonitis. I also used similar specimens which had been hardened in absolute alcohol, and with the same results. The portions of tissue were invaded by vast numbers of wandering cells and slowly liquefied.

Hallwachs, Rosenberger, Salzer, and others have recently studied the subject of the encapsulation of foreign bodies, and Salzer says that those which are smooth and solid become enclosed in a delicate connective-tissue capsule, while the porous, fibrous, rough foreign bodies are most apt to heal into the scar tissue with the formation of very thick layers of connective tissue.

Diagnosis of Inflammation.—In the *diagnosis* of inflammation—i. e., of the four above-described cardinal symptoms, redness, swelling, heat, and pain—we make special use of inspection and palpation of the affected part in case it can be seen and touched. If the inflammation is located on the outer surface of the body the diagnosis is simple, but it is more difficult if the inflammation is situated more deeply. By palpation of the inflamed tissues we attempt to determine whether the inflammatory focus contains pus—i. e., whether it "fluctuates" or not. Every fluid, and consequently pus or serum, contained in a cavity having yielding, elastic walls will give fluctuation or a wave movement when the fluid in this cavity is set in motion by intermittent pressure

with the index or middle finger. The detection of fluctuation is of the greatest practical importance. If the pus is contained within firm, unyielding walls, such as bone, or in deeply situated tissue with thickened rigid walls, fluctuation cannot be made out. Furthermore, it must not be confused with the pseudo-fluctuation manifested upon palpation of soft elastic parts; but a little experience will soon teach the distinction between the fluctuation of an elastic cavity filled with fluid and the pseudo-fluctuation of soft elastic tissues such as the muscles of the thenar eminence, soft fatty tumours, etc. Puncture with an aspirating syringe is an exceedingly useful diagnostic measure for determining the nature of the contents of an inflammatory focus (see page 74).

We also employ the sense of hearing in the diagnosis of an inflammation by noting, for example, whether any friction sound is produced by the rubbing together of two opposed inflamed surfaces. Hueter has constructed instruments analogous to the stethoscope used in the diagnosis of diseases of the thoracic viscera; they are a dermatophon, an osteophon, and a myophon, for the diagnosis of surgical diseases of the skin, bones, and muscles respectively, and they consist of an elastic tube fitted to an ear-piece. We shall refer to this apparatus in diseases of bone, but it may be said here that hitherto it has not been brought into general use.

The febrile disturbance accompanying an inflammation is determined by accurate measurement of the body heat by means of a thermometer placed in the axilla, or, better, in the rectum (see § 62, Fever).

Among other aids to diagnosis I should mention the probe, which is used to ascertain the direction and length of a fistulous tract, or the presence of a foreign body. There are also instruments designed for special organs, such as the urethra, bladder, stomach, etc., and a great number of contrivances for inspection of the nose, larynx, bladder, eye, etc.

These general remarks will be sufficient until we return to the diagnosis of inflammations of the separate parts of the body.

Treatment of Inflammation.—At present we can only deal briefly with the *treatment* of inflammation, as we shall have to come back to the subject in detail for each separate part of the body. From a prophylactic standpoint it is best to treat every injury, no matter how trifling it may be, on antiseptic principles, after the manner described in a former chapter. In general, the treatment of an acute inflammation consists in the use of suitable antiphlogistic measures, particularly the proper position of the inflamed part, such as elevation in the case

of an extremity, in the application of ice, and in the prompt evacuation of the pus or infiltrating exudate by incision.

Blood-letting by leeches, cupping, and scarification used to be much in vogue for diminishing the amount of blood contained in an inflamed portion of the body, but now this practice has very properly been given up. The counter-irritation method of treatment by cutaneous irritants, such as the moxa, issue, red-hot iron, painting with tincture of iodine, and the application of vesicants, is also old-fashioned. It would require too much space to give the outlines of treatment for inflammation according to the location and causes of the latter, and it can be done more satisfactorily in the discussion of the treatment of inflammations of the separate organs. The treatment of the general febrile disturbance due to inflammation will be considered in the treatment of fever (§ 62).

§ 59. **Morphology and General Significance of Micro-organisms.**—By *micro-organisms* or *microbes* is understood a class of minute living organisms which belong to the lowest forms of plant life or stand on the border line between plants and animals. The majority of the micro-organisms have a diameter of only about one micromillimetre or less. They multiply with extreme rapidity, and are able to live in widely differing degrees of temperature, some in acid and others in alkaline solutions of simple compounds (with the exception of carbon dioxide), as well as of more complex nourishing substances.

The micro-organisms play a very important part in the economy of nature. They excite fermentation and decomposition, and are parasites in living plants, animals, and man, causing in some cases disease and death. By fermentation and decomposition the micro-organisms disintegrate considerable amounts of organic material in a short period of time with the evolution of gas. The change of sugar into lactic acid (sour milk), the lactic into butyric acid, and alcohol into acetic acid, are all processes of fermentation caused by micro-organisms. We make use of micro-organisms in the preparation of many alimentary substances, such as bread, cheese, beer, wine, etc., while on the other hand, as a result of the fermentative and putrefactive action of these low orders of organisms, our food may be rendered unfit to eat.

Micro-organisms also produce poisonous matters (ptomaines, toxines) which are dangerous to the health and life of man. Numerous acute and chronic inflammations, particularly the surgical diseases of wounds, are due to the presence of micro-organisms.

Evidence of the Bacterial Origin of many Infectious Diseases, especially the Diseases of Wounds.—Under normal conditions we find no micro-organisms in the blood and internal organs of healthy human beings and animals;

is has been proved beyond a doubt by Meissner and many other investi-ators. On the other hand, we observe in the various infectious diseases, articularly the surgical-wound diseases, certain micro-organisms in the lood and internal organs, and we know that every infectious disease is due o some specific, plainly distinguished class of micro-organism. These gain ccess to the body from without by means of the inspired air, the food, water, r by contact with the surface of the body, especially if there is an interrup-tion of continuity in the skin or mucous membranes. The striking results obtained by antisepsis and the aseptic method of operating and treating wounds demonstrate that the infectious-wound diseases are caused by the entrance of micro-organisms into the wound from without. If we perform an operation, taking every precaution not to introduce microbes by our hands or instruments, or from the patient's own skin, into the wound, or, briefly, if we operate aseptically, as we have learned in a previous chapter, with everything germ-free and sterile, and then dress the wound with germ-free (sterilised) materials, such a wound will invariably heal without inflam-mation and suppuration *per primam intentionem*, or, in other words, by immediate agglutination of its borders, and without giving rise to fever. If there is a transgression of the rules of asepsis or antisepsis in performing an operation or treating a wound, and if micro-organisms get into the wound, inflammation and suppuration and other wound diseases, accompanied by a corresponding febrile disturbance, will result. If an infected wound is treat-d with disinfecting substances, such as bichloride (1 to 1,000–5,000) or three-per-cent. carbolic solutions, the micro-organisms are prevented from further development and the existing inflammation or suppuration is modified or checked, provided it has not already become too far advanced and no general systemic poisoning has taken place. A further proof of the microbic origin of the infectious diseases is furnished by the successful results of transmis-sion from animal to animal. Cultures of a particular kind of bacteria which had caused a certain infectious disease, were introduced into the body of an animal and here produced the same disease, and the same kind of bacteria could be isolated from the diseased tissues. The micro-organisms damage the human organism in a double manner—viz., by the formation of the poison-ous products of their metabolism, and by multiplying very rapidly and invad-ing new portions of tissue.

The Different Kinds of Micro-organisms.—We recognise four large classes of micro-organisms: I. The fungi or moulds. II. The sprout-ing or yeast fungi (saccharomycetes, blastomycetes). III. The fission fungi, bacteria (schizomycetes). IV. Mycetozoa and protozoa.

I. **Fungi.**—Moulds form the well-known green, yellow, whitish, or black kinlike covering found upon all sorts of dead organic substances. They sually consist of two functionally distinct parts, the mycelium and the ger-inal hypha or zygospore. The mycelium consists of branching, usually inted threads, which anastomose with one another and proliferate in the itrient substrata. The zygospores spring from the mycelium and produce d carry on their ends the seeds or spores (Figs. 248 to 251). The latter are und or elongated cells generally having a dense enveloping membrane,

and after separation from the zygospore are capable of forming another fungus with its zygospore. The spores can retain their vitality in a dry state for from two to ten years. Numerous species of fungi are distinguished by the manner in which the spores form upon the zygospores. Occasionally the spores undergo segmentation by transverse division of the terminal cells at the extremity of the zygospore (conidia). In other fungi the terminal cell develops into the so-called sporangium or ascus, in the interior of which the spores form by division of the plasma (ascospores). In still others two zygospores grow one within the other, and the so-called oöspores develop at the point of junction of the two spore carriers. The same fungus will occasionally form its spores in several different ways, depending upon the conditions in which it exists (conidia and ascospores).

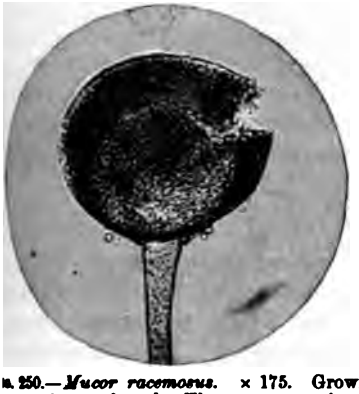
Conditions Suitable for the Life of the Fungi.—The fungi are found upon every description of dead substance, and upon substances which contain a relatively small amount of water and have an acid reaction, thus differing from the bacteria. For making pure cultures of fungi, the best materials are boiled potatoes, bread pulp, and gelatine, or the agar mixture rendered acid by the addition of two to five per cent. of tartaric acid, to prevent bacteria from taking root along with the fungi. The temperature is an important matter, some species thriving best at + 15° C. (59° F.), and another at + 40° C. (104° F.). The spores will only form when there is plenty of air, oxygen being essential, and consequently most of the fungi will not multiply in the interior of animal tissues nor in blood; they ordinarily exist only upon such portions of the body as are freely exposed to the atmospheric air.

Penicillium.—The commonest fungus is the *Penicillium glaucum* (Fig. 248). It grows in distilled water and many kinds of medicine, best at a temperature of from 15° to 20° C. (59° to 68° F.), while at 38° C. (101° F.) it gradually dies. The mycelium has a flocculent, white appearance, turning green after the formation of the spores. The latter do not grow when introduced into warm-blooded animals by injection into the blood or by inhalation, and they may remain for weeks in the liver and spleen.

Fig. 248.—*Penicillium glaucum.* × 180.

Fig. 249.—*Oidium lactis* grown on milk and then cultivated in bouillon. × 250.

Oidium.—There are numerous species of the oidium which flourish partly on a dead substratum and partly (like mildew) upon living plants. They regularly present upon sour milk. Mycelium and spores are white. ey thrive best at a temperature between 19° to 30° C. (50° to 86° F.). They



. 250.—*Mucor racemosus.* × 175. Grown on moist rye bread. The outer capsule of the sporangium has been broken by pressure against the cover-glass, and spores are seen coming out.

Fig. 251.—*Aspergillus fumigatus*, a pathogenic fungus cultivated on moistened bread. × 250.

nsist partly of cylindrical bodies lying together and forming an angle with ch other, and partly of long branching and segmented threads. Many of e cells contain small and large round bodies (Fig. 249). Fungi of the oidin class are found in favus, pityriasis versicolor, and herpes tonsurans.

Monilia.—The monilia is distinguished from the oidium by its zygospore, hich takes a bushy-shaped, branching form as it springs from the mycem. Cultures of monilia conidia if inoculated into the skin of the dove's ck will cause thrush (see also page 260).

Mucor.—There are many species of mucor, some of which thrive best at temperature of 37° C. (98.6° F.), and cause death in rabbits when their ores are injected into the blood-vessels in large amounts. There are then und in the internal organs, particularly the kidney, a great number of all fungi which do not fructify. They are chiefly found in man, in the ternal auditory meatus. The spores are developed in sporangia (Fig. 250).

Aspergilli.—They generally germinate like the conidia, less frequently ving ascospores. The *Aspergillus glaucus* is greenish yellow, is harmless regards warm-blooded animals, and is generally found in damp walls, eserved fruits, etc. The *Aspergillus fumigatus*, *flavescens*, and *subfuscus* e pathogenic, and the most favourable temperature for their growth is about ° C. (98.6° F.). The injection of large numbers of the spores will kill rabs, numerous foci of the fungus being found in the heart, liver, and kidys. Spores of *Aspergillus fumigatus* exist chiefly in the air-passages of ds. In man, colonies of this species of aspergillus have been observed in bronchi, lungs, external auditory meatus, upon the cornea, in the facial ities, etc.

Pathological Importance of the Fungi for Man.—The pathological bear- of the fungi upon man, as ascertained by experimental and clinical

observations, is briefly as follows: It is well known that the fungi occasionally find lodgment in the epithelium of the skin and mucous membranes, and in the former situation give rise to favus, herpes tonsurans, pityriasis versicolor and other skin diseases, and in the latter to thrush. Later investigations have led most authorities to believe that the exciting cause of thrush is a yeast fungus (see pages 259 and 260 and Fig. 253). Zenker found in the brain of a child affected with thrush multiple abscesses with sprouting spores of the thrush fungus in their centres. The question as to whether fungi can grow in the living tissues of warm-blooded animals has been answered in the affirmative by both Grohé and Grawitz. This is particularly true if the fungi have first become adapted by "accommodative cultivation" to the heterogeneous conditions of alkaline blood at a temperature of 39° C. (Grawitz). Further experiments made by Koch and others have demonstrated that there are pathogenic fungi which are capable of development in the tissues of warm-blooded animals without having undergone any previous particular kind of cultivation, while the non-pathogenic fungi never possess this power even though they have first been subjected to cultivation. The non-pathogenic fungi include the *Penicillium glaucum*, the *Aspergillus glaucus* and *niger*, the *Mucor mucedo*, and *stolonifer*. The species which are certainly pathogenic include: 1. The *Aspergillus fumigatus* (Fig. 251), distinguished from the *Aspergillus glaucus* by its very small size and that of its spores, its dirty green colour, the manner of its growth, its poor development at ordinary temperatures, and the very rapid growth manifested in temperatures equal to blood heat. The *Aspergillus fumigatus* is present in bread, and is readily cultivated on dough kept at a temperature of 39° to 40° C. (102.2° to 104° F.), as a dark-green fungous covering. 2. The *Aspergillus flavescens* is similar to the *Aspergillus fumigatus*, and is characterised by its yellowish-green colour. 3. The *Mucor rhizopodiformis* is distinguished from the non-pathogenic mucor (*Rhizopus*) by the greyish-brown colour of its mycelium, the large size of its individual parts, its small, round, colourless spores, and by the egg-shaped columella dilated at its top. 4. The *Mucor corymbifer* is known by the snow-white colour of its mycelium and its characteristic form.

Internal fungous diseases arising spontaneously in, for instance, the lungs and intestinal tract, are seldom seen in man, as the pathogenic fungi (of the aspergillus and mucor varieties) will only thrive at a high temperature, and consequently are not very plentiful in the air, water, or alimentary substances. Furthermore, the fungi are only pathogenic when they exist in great numbers, while the system is capable of overcoming a few of them without itself suffering harm (Grawitz), and their increase by means of spores does not take place in living tissue. Fungous diseases are most easily excited by intravenous injection of the organisms. Lichtheim's mucor injections proved fatal in rabbits in every case, while dogs were not affected at all. Morse, Kaufmann, and Schulz caused animals to inhale and swallow large amounts of pathogenic fungi without producing any ill effect; Lichtheim noted only a scanty and stunted vegetation in the lungs after inhalation. In man there is occasionally observed a pneumomycosis aspergillina (*Aspergillus fumigatus*) and a pneumomycosis mucorina, secondary to already existing pulmonary disease. There is also a keratomycosis aspergillina, a corneal lesion, and an aspergillus mycosis of the facial cavities and the ex-

rnal auditory meatus (oto- or myringo-mycosis aspergillina), produced by the *spergillus fumigatus*, *flavescens*, and *nigrescens*. According to Carter, he Madura foot, a disease like elephantiasis, endemic in India, and characterised by the formation of warty lumps, suppurating in their interior and erminating in death after about a year, is caused by a fungus, the *Chionyphe Carteri*, related to the *Mucor stolonifer*; but other investigators have disputed this. As a general thing, man may be said to be immune to the pathogenic fungi hitherto identified; but under conditions not yet understood these fungi may take on a fatal activity, as exemplified by the above-mentioned case of Zenker's, and a recently described and interesting case of Paltauf, in which a man died in coma after what appeared to be an enteritis and peritonitis. In the brain, lungs, and intestine were found inflammatory foci, or abscesses, containing mycelia of the mucor variety (*Mucor corymbifer*). It is by no means impossible that still other new forms of fungous disease may be found to have their existence in man. All the facts which are known as regards the pathogenic fungi are of great surgical interest. The fungi play a very important part in the production of diseases in plants and low orders of animal life, such as the grape disease, the potato disease, the "rot" of grain, the muscardine disease of silkworms, and various diseases in insects, etc.

II. **The Yeast Fungi** (*Blastomycetes*).—The yeast fungi (Fig. 252) are round, oval cells of different sizes, varying from two to fifteen micromillimetres in diameter, having a thin enveloping membrane and granular protoplasm, in which there are frequently vacuoles (Fig. 252). They multiply by budding or putting forth daughter cells, which finally become separated from the mother cells by a partition, and either remain in contact with their parent cell for a consider-

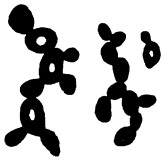


Fig. 252.—Yeast fungus. *Saccharomyces cerevisiæ*. Vacuoles are present in some of the larger cells.

Fig. 253.—*Saccharomyces albicans*. Thrush fungus. × 250. (Heim.)

able time, forming more or less long chains, or they become entirely separated. Many, though not all, of the yeast fungi produce in solutions of sugar alcoholic fermentation, changing grape sugar into carbonic acid and alcohol. The true yeast fungi which cause fermentation (saccharomycetes) must be distinguished from the other fungi of the same class. The mycelia of the typical mould fungus—for instance, the mucor species—can form chains and can cause alcoholic fermentation in a solution of sugar. Macroscopically the yeast plant forms a white cloudy sediment in a fermenting fluid, or a white scum over the surface of alcoholic fluids which are spoiling. In solid nutri-

tive media (gelatine) the yeast fungus makes spores by developing free cells within the enlarged mother cell (ascospores). Beer-wort and decoctions of malt or prunes, to which sugar is afterwards added, form the best culture media, but they must be mixed with one per cent. of tartaric acid to keep out the bacteria.

The pathological interest of the yeast fungi is limited; they occasionally give rise to fermentation in the stomach. Most authorities hold that thrush, a common inflammation of the mucous membrane of the mouth and throat, is caused by a yeast fungus (*Saccharomyces albicans*, see Fig. 253); other authorities have considered this a mould fungus. A disease occurring late in the autumn is caused by a yeast fungus (*Empusa muscæ*). More serious diseases have of late been found to be due to certain yeast fungi. Busse described a fatal infection in a man of thirty-one, caused by a yeast fungus, which ran a course similar to a chronic pyæmia. At first an abscess developed in the left tibia, then ulcers in the skin of the face, and further diseased foci in the right ulna and the sixth rib on the left side. Death occurred thirteen months from the beginning of the disease. The autopsy showed extensive destructive changes in both kidneys, both lungs, and spleen, and small nodules on the pleura resembling tubercles. All the foci contained a white yeast fungus in great amounts; it was present within the cells. Pure cultures of the fungus cells proved to be pathogenic for dogs and mice. The latter died in from four to ten days after subcutaneous injections of fluid cultures. This disease, described by Busse, resembles actinomycosis most closely. Buschke has also made observations regarding the pathogenic nature of mould fungi in man. According to him, the fungi are situated in part in the superficial epithelium of the skin and mucous membrane, and give rise here to ulcers, catarrhal inflammation, etc., and in part penetrate into the interior of the animal and human body, causing either a variety of septicæmia or only local changes in the tissues. It is possible that in the future many of the diseases of the skin, mucous membranes, and serous surfaces will be found to be due to the yeast fungi. Maffucci and Sirleo have also come to the conclusion that there are pathogenic and yeast fungi which under certain conditions may give rise to septicæmia, suppuration, or chronic inflammatory new-formations of the type of the granulation tumours.

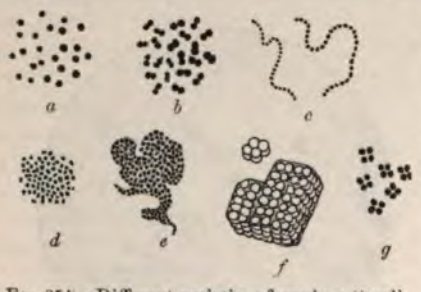


FIG. 254.—Different varieties of cocci: *a*, Smaller and larger cocci; *b*, diplococci; *c*, chain coccus (streptococcus); *d*, *e*, clusters of cocci in the form of a bunch of grapes (staphylococci); *f*, sarcina (packet coccus); *g*, *Micrococcus tetragonus*.

III. **The Bacteria** (*Schizomycetes*).—The bacteria (from *τὸ βακτήριον*, a small rod, from the rod shape which many of them have) are very small, simple cells of a low order of vegetable life related to the lower orders of algæ. They are divided into several distinct classes, according to their shape and the effects which they produce. Nevertheless,

under altered conditions in their life the bacteria of one class change their shape and function to a greater or less degree. There are chiefly to be distinguished: 1. The micrococci. 2. The bacilli. 3. The spirilla.

FIG. 255.—Tubercle bacilli from the sputum of a thirty-eight-year-old phthisical patient. The sputum was dried on a cover-glass and stained with fuchsin and methylene violet. × 700.

FIG. 256.—Blood from a mouse with anthrax, dried on the cover-glass and stained with methyl violet. Red blood-corpuscles and anthrax bacilli. × 700.

1. *The Spherical Bacterium* (*Micrococcus or Coccus*).—The micrococci are small, round, or oval cells, which by division or fission always produce in turn the same round cells. The micrococci exist either as isolated spherules (Fig. 254, *a*), or they remain in pairs after dividing (diplococcus, Fig. 254, *b*), or the spherules cling together in chains (streptococcus, Fig. 254, *c*). In other instances they form irregular groups (staphylococcus, Fig. 254, *d*, *e*). Large groups or colonies bound together by some sticky material such as mucus are called zoögloea. Sometimes the micrococci develop in groups of four (merismopædia, merista, Fig. 254, *g*), or they are joined together in cubes (sarcina, Fig. 254, *f*). The sarcina is found in the stomach of man, as *Sarcina ventriculi*, when fermentation is present.

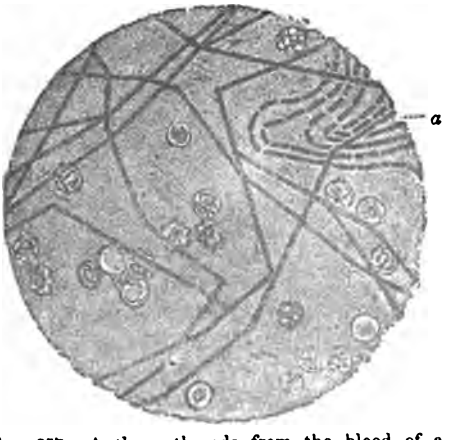


FIG. 257.—Anthrax threads from the blood of a mouse. Culture in bouillon at 24° C., ten hours old: *a*, threads made up of single bacilli. × 700.

2. *Rod-shaped Bacteria* (*the Bacillus*).—In all bacilli the longitudinal diameter exceeds the transverse, and their size varies very greatly (Figs. 255, 256, 257). The bacilli divide transversely, and, like

the cocci or the streptococci, they form longer or shorter threads by remaining attached to one another after division (leptothrix). These threads, in contrast to the mould fungi, never become branched, though several threads lying next each other may give the appearance of branches. Particularly the anthrax bacilli (Fig. 257) and the bacilli of malignant œdema have the form of long threads. Many bacilli possess an enlargement at their centre or end, and such spindle-shaped or tadpole-formed rods are known as clastridia.

Fig. 258.—*Spirochætæ Obermeieri.* × 700.

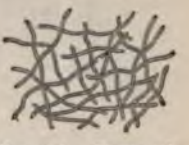


Fig. 259.—Group of *Vibrio serpens.* × 650 (Flügge).

3. *The Spiral-shaped Rod Bacillus* (*Spirillum*).—The spirilla (Fig. 258) have the appearance of spirally twisted threads or fragments of cork-screws. The bacterium which has the twist but slightly marked is known as a vibrio (Fig. 259).

Under each of the separate classes of bacteria there are many varieties and species which are of great importance from a diagnostic standpoint. Thus there are small or large, oval or lancet-shaped cocci, also slender and broad bacilli, etc. Within one species differences occur depending upon the conditions of nourishment or age.

The Structure and Reproduction of Bacteria.—The bacteria, like other vegetable cells, consist of an inner portion surrounded by an enveloping membrane. Their interior is made up of albuminoid matter, fats, salts, and water, while the enveloping membrane is probably allied to one of the cellulose bodies belonging to the hydrocarbon compounds. C. Fränkel and others consider it doubtful whether or not a nucleus exists within the protoplasmic contents of these cells.

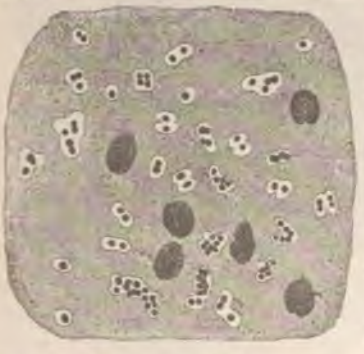


Fig. 260.—Diplococcus of Fränkel (capsule coccus). Pus taken from a case of empyema. × 1,000.

The bacteria are often surrounded by a gelatinous enveloping substance, which facilitates the formation of the above-mentioned bands. It can in some cases be made visible by the usual staining materials, but in others a special treatment is necessary with iodine.

Movements of Bacteria.—Many bacilli and spirilla are capable of active movement, and of moving from one spot to another. The micro-

not possess the power of locomotion, but are seen to have only lous molecular "Brownian" movement; but Löffler and Menve recently discov- o species of micro- hich do have the f motion. The loco- of the bacilli and which are capable of is brought about by organs called cilia la. Löffler, by means cial method of stain- demonstrated these in a number of the

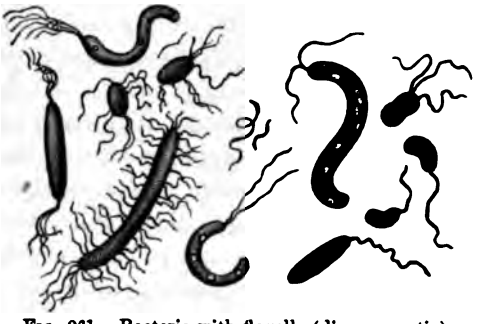
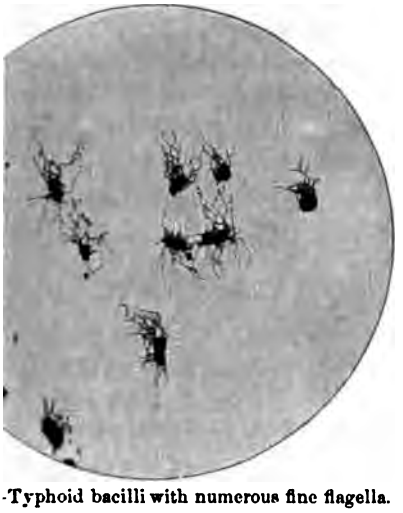


FIG. 261.—Bacteria with flagella (diagrammatic).

nportant pathogenic bacteria. The different forms of flagella wn in Fig. 261. They are found either at one end only or at ds, and are single, double, or in the form of bunches. Many , such as the typhoid bacillus and the bacillus of malignant have their entire periphery covered with fine cilia, causing resemble a spider or a centipede (Figs. 261 and 262).

lace of Löffler's stain for flagella, Bunge recommends the following which acquires its full efficiency only after long exposure to the air: Three parts concentrated solution of tannin, one part five-per-cent. liquor ferri chloridi, to which is added one cubic centimetre of concentrated aqueous solution of fuchsin to ten cubic centimetres of the mixture.



-Typhoid bacilli with numerous fine flagella.

Reproduction of Bacteria.—Some bacteria multiply by direct division or fission; the cells become somewhat increased in length, and form two separate and distinct individuals, or they remain adherent to each other after division (diplococcus, streptococcus, vibrio). The mul- power of the fission fungi is enormous. If, as Flügge says, the length of time required for fission to occur is one hour, there formed from each bacterium within twenty-four hours about

sixteen million new ones. Many bacteria, such as the *Bacillus subtilis*, the *Bacillus anthracis*, and the bacillus of malignant œdema, propagate themselves by the formation of spores, which is an actual fructification in the interior of the cells—that is, by the formation of a strongly refracting, shining body, which is set free by the atrophy of the remainder of the cells (Fig. 264). Each cell forms only a single spore. If the spores find lodgment in a nutritive medium, they sooner or later germinate, and each spore will develop into a cell similar to the mother cell from which the spore originated. Spore formation has been observed in various species of bacilli and in some of the spirilla, but hitherto in none of the micrococci. The bacteria undergo spore formation for the purpose of propagating the species, particularly when at the height of their development and when the conditions governing their nutrition and growth are at the best. By subjecting the protoplasm of the bacteria to certain injurious influences their power of spore formation can be temporarily or permanently arrested (Lehmann, Behring, etc.). From a pathological standpoint the capability which the spores possess of withstanding noxious influences, such as dryness, heat, cold, or chemical substances, is of great importance. The spores of many bacteria can retain their vitality unimpaired for as much as a year when kept in a dry condition, or even in absolute alcohol. A dry heat of 140° C. (284° F.) destroys their power of reproduction with certainty only after many hours,

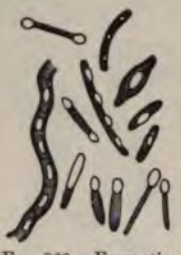


Fig. 263.—Formation of endospores (diagrammatic).

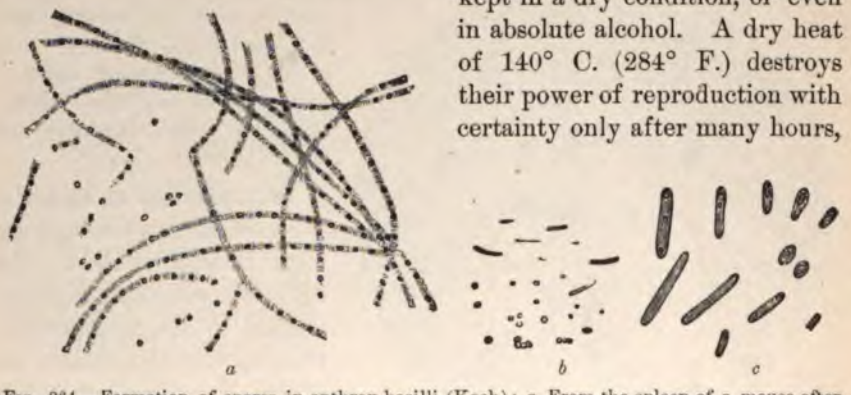


Fig. 264.—Formation of spores in anthrax bacilli (Koch): *a*, From the spleen of a mouse after twenty-four hours' culture, × 650; *b*, germination of the spores, × 650; *c*, specimen *b* magnified 1,650 times.

and they can withstand boiling for several minutes. Globig had to subject the spores of the potato bacillus to the action of steam for more than four hours before they died. This great power of resistance which spores possess is probably due to the remarkably tough

character of their enveloping membrane, and perhaps also to the chemical composition of their interior. The spores of the different kinds of bacteria vary very much in their capabilities of resisting noxious conditions.

Arthrospores.—Besides the endospores, or those which are formed in the interior of the cells, there are also arthrospores (Fig. 266). They owe their existence to the fact that certain segments of a chain, string, or cluster of bacteria have more vitality than the others; entire cells separate themselves from their surroundings and form new chains or groups, and thus propagate their species after the other bacteria have died. The arthrospores have no other typical means of recognition, and they are not particularly resistant to unfavourable influences.

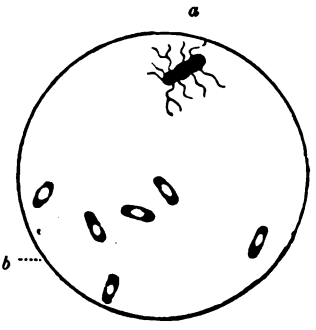


Fig. 265.—Spore formation (*b*) in bacilli of malignant œdema. Agar culture. *a*, bacillus with flagella. × 1,000.

The Occurrence of Bacteria and the Conditions Suitable for their Life.—Bacteria are found everywhere. The air, earth, water, and the things which they contain, our clothing, our food, skin, etc., support a vast number of these invisible living beings or plants, and only the normal organs, the blood and the lymph in the healthy body of man and animals, are free from them. Bacteria do not originate by spontaneous generation, or *generatio æquivoca*—i. e., by springing from molecules of another kind—but they grow only from spores of their own species (Pasteur and others). The above-described spores are the principal means for the preservation of the various kinds of bacteria.

Fig. 266.—Arthrospores (diagrammatic).

From the fact that bacteria are found almost everywhere, it follows that they require but little for their development; the smallest amount of organic material is capable of supporting them. They require chiefly nitrogen and compounds of carbon. The amount of nutritive matter which the different species need varies very much, but in general they require, besides inorganic material, food which contains nitrogen (albumen), or is free from nitrogen (sugar, glycerine). It is very important that the nutritive medium should be alkaline, or at least neutral in reaction, as bacteria, with a few exceptions, do not grow in an acid medium. The bacteria which grow exclusively in dead organic material are called the *obligate saprophytic*, while the *obligate parasitic bacteria* are those

which only grow in the living body of a warm-blooded animal. But there are a vast number of bacteria which are saprophytic (living upon dead organic matter), and exist as parasites, the so-called *facultative parasitic* or *facultative saprophytic fungi.*

Adaptation of Bacteria to Unsuitable Nutritive Media.—Bacteria have the power of adapting themselves gradually to media which are unfavourable to their development, and are thus able to accommodate themselves even to antiseptic solutions, like bichloride, when they are allowed to become gradually accustomed to it. Trambusti succeeded, in the case of Friedländer's pneumococcus and other bacteria (the anthrax bacillus and the *Staphylococcus pyogenes aureus*, etc.), in increasing the concentration of the bichloride of mercury contained in the nutritive bouillon from 1 to 40,000 up to 1 to 2,000 without interfering with their development. But if, on the other hand, these microbes were placed immediately in a bichloride bouillon mixture of a strength of 1 part bichloride to 15,000 of bouillon, their development ceased immediately.

Influence of Oxygen.—Oxygen plays a very important part in the life of bacteria. Many species will grow only in the presence of free oxygen (*obligate aërobic bacteria*), while the *obligate anaërobic bacteria* will only do so when free oxygen is absent from their nutritive medium. Other bacteria—and they include the majority of the pathogenic bacteria—are facultative aërobic and facultative anaërobic; i. e., their growth is not dependent on the presence of oxygen, though the facultative aërobic flourish better *with* oxygen, and the anaërobic *without* it.

Influence of Temperature.—Temperature has an important influence upon them. A certain amount of warmth is, of course, necessary for the development of bacteria as well as for any kind of life, and each species has its own temperature—that is, there is a range of temperature for each species which is best adapted for the growth of that species. The saprophytes are best suited by the ordinary temperature of a room (20° to 25° C.—68° to 77° F.), the parasites by blood heat (35° to 40° C.—95° to 104° F.), while other classes are capable of growing at temperatures close above the freezing point, and even below it. When the temperature is abnormally high or low the bacteria become benumbed by the heat or cold, and if the temperature rises or falls still more they perish. It is well known that the spores have a remarkable power of resisting extremes of temperature. The limits of temperature compatible with the development of most of them lie between 40° and 50° C. (104° to 122° F.); of others, between 60° and 70° C. (150° to 168° F.). The pus cocci, when in a dry state, can retain their vitality for a long time at a temperature of 80° C. (186° F.). Globig

and Miquel have discovered bacteria which can still grow and multiply at a temperature ranging between 60° and 70° C. (150° to 168° F.).

Influence of Light.—Exposure to sunlight has a deleterious effect upon certain bacteria, such as the tubercle and anthrax bacilli, which die comparatively quickly under the direct action of the sun.

Influence of the Galvanic Current.—The bactericidal action of the galvanic current is due, according to Charrin and Burci, to electrolysis in its surrounding fluid; nascent iodine has a particularly strong action. Cultures of different bacteria (staphylococci, streptococci, anthrax spores, etc.) in a one- to four-per-cent. solution of potassium iodide if subjected to a constant current of two to ten milliampères are killed at the positive pole, when iodine is set free, in five to thirty minutes, but not at the negative pole. In the tissues the constant current seems to have no particular effect upon bacteria.

The Products of the Life and Metabolism of the Bacteria.—By means of their vital activity the bacteria generate certain products of metabolism, of which some exert a restraining influence upon the growth of the bacteria; such products are carbonic acid, lactic acid, acetic acid, etc.; upon other species of bacteria the increasing alkalinity of the nutritive medium acts unfavourably. Many bacteria generate ferments or soluble organic bodies which readily change such complicated insoluble compounds as albumen or starch into soluble substances, acting in the same way as the pepsin or ptyalin does in animal organisms. In many bacteria there is a peptonising ferment which will liquefy gelatine, and this is a matter of much importance for diagnostic purposes. In fact, the various species of bacteria have been divided into the general classes of those which liquefy and do not liquefy gelatine.

Ptomaines and Toxines.—Bacteria are, furthermore, the cause of fermentation and decomposition, and in this connection it was first discovered that bacteria form poisonous products of metabolism called ptomaines and toxines. It has long been known that certain poisonous products are developed during decomposition. In 1863 Panum isolated a substance which he called the "poison of decomposition," and Bergmann and Schmiedberg a crystalline body which they called sepsine. At present we know that the cause of many infectious diseases lies in the action of those poisons which are produced by the micro-organisms. Ptomaines are nitrogenous substances which are formed from the constituents of the animal organisms by the metabolism of the bacteria. As they are derivatives of ammonia they have erroneously been called alkaloids. Ptomaines that have a poisonous action are called toxines. A large number of these ptomaines have been isolated in a pure state.

Nencki was the first to isolate collidin and determine its formula. Many other investigators have since devoted themselves to the study of ptomaines and toxines. Brieger has isolated several ptomaines and toxines from cultures of bacteria—e. g., peptotoxine, neurine, neuridine, cadaverine, muscarine, phlogosin, choline, etc. He also obtained very poisonous toxines from cultures of typhoid and tetanus bacilli (typhotoxine, tetanine, tetanotoxine). Their very poisonous character was demonstrated by the inoculation of animals. Some toxines have a similar action to morphine, curare, or atropine. Peptotoxine causes death in the animals experimented upon with symptoms of paralysis; and neurine, according to Brieger, acts like muscarine, causing salivation, contraction of the pupils, disturbances of respiration and circulation, and clonic spasms. This explains the general systemic poisoning of various kinds due to bacterial infection of wounds, and in part the cases of poisoning caused by ingestion of decomposing food with the ptomaines it contains (meat, sausage, milk, and cheese poisoning). The toxines can be separated from the bacteria by filtration through porcelain, and then, by injecting the toxines beneath the skin of animals, it is possible to study their poisonous manifestations. If cultures of bacteria are subjected to a temperature of 60° C., the micro-organisms will perish, and the poisonous effects of many of the ptomaines can be studied; but others are destroyed by a high temperature. Toxines, which belong to different groups of chemical bodies, are in some instances resistant to heat, and in others non-resistant. Buchner called those substances within the bacterial cells which resist heat, proteins. Those substances which do not resist heat, and are found in the culture fluid, are called by Brieger and Fränkel toxalbumins, on account of their supposed albuminous nature. Hankine calls them albumoses, but the general term *toxines* is better. The nature and composition of the nutritive medium plays an important part in the formation of the toxines produced by any particular kind of bacteria—i. e., the same bacteria do not under all circumstances produce the same toxines. Even harmless bacteria, like the *Micrococcus prodigiosus*, may, when combined with some second species also non-pathogenic, become dangerous to the animal economy. The specific poisons of many bacteria —for example, the tubercle bacilli—are not found in the nutritive medium, but chiefly in the bodies of the bacteria themselves, so that tuberculosis can be excited by dead tubercle bacilli (R. Koch, Prudden, Hodenpyl, etc.). Buchner showed even earlier that the above-mentioned proteins which are intimately connected with the bacterial cells cause inflammation and have a toxic action. Buchner, Lange, and F. Roemer pointed out that these poisonous bacterial pro-

teins and certain toxines have a great power of attraction for the leucocytes (chemotaxis), and after intravenous injection cause an increase in the number of the leucocytes (leucocytosis). The properties possessed by these bacterial proteins of causing inflammation, and particularly fever (general toxic action), have become more and more firmly established by the latest investigations. (Antitoxines, see page 277.)

Pigment Formation.—Many bacteria form colouring matter (Figs. 267–269) of many different shades, such as white, black, red, blue, yellow, green, and brown, giving to the culture, and often to a great part of the nutritive medium, a characteristic tinge. The pus

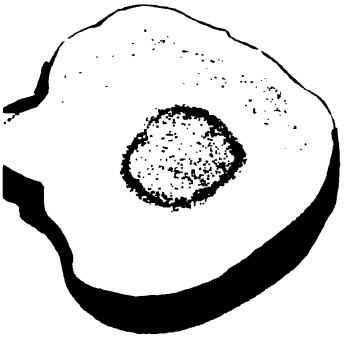


Fig. 267.—*Staphylococcus pyogenes citreus*, potato culture.

Fig. 268.—Streak culture of *Bacillus prodigiosus* on agar.

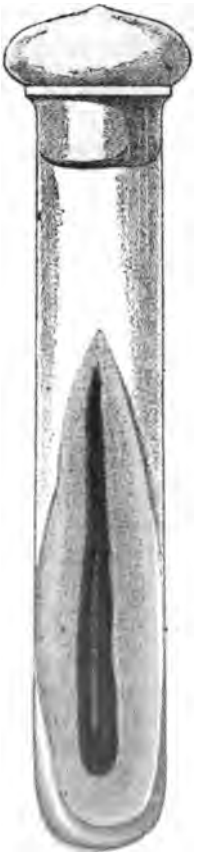


Fig. 269.—Streak culture of *Bacillus pyocyaneus* on agar.

is sometimes coloured by bacteria. The pigment bacteria, in all probability, possess a chromogenic body, which when exposed to the influence of oxygen changes to a colouring matter.

Phosphorescence.—Many bacteria are phosphorescent—i. e., they are luminous in the dark (Fischer).

Products of the Bacteria—Different Effects of the Products.—Arloing and Courmont distinguish three principal classes of the products of the pathogenic bacteria: 1. The substances precipitable by alcohol (diastases, by acidified alcohol (toxalbumens), by Millon's reagent (peptones). Diastases and toxalbumens are capable of dialysis only to a slight extent. 2. The substances

which are soluble in alcohol and ether and can be precipitated by acetate of lead and bichloride of mercury are dialysable and are but slightly altered by heat (ptomaines, alkaloids). 3. The volatile substances, coloured compounds of carbon, etc. Some of the products have toxic, some predisposing, and some immunifying properties, and they have all been isolated from various species of bacteria (Behring, Fränkel, Rovet, etc.).

The marasmus accompanying acute and chronic diseases due to bacterial infection is caused by the products of the metabolism of the bacteria, as Mannetti has proved in the case of the metabolic products of the *Staphylococcus pyogenes aureus* and *albus*.

The Limitations to the Growth of Bacteria; their Death.—Various influences place restraints upon the growth of the bacteria, such as too low or too high temperatures, absence of water, the addition of certain chemical substances or bacterial poisons to their nutritive medium, etc.

If noxious influences are not permitted to act too intensely upon the bacteria the latter become weakened, and this weakening process can be kept up through several generations, causing the pathogenic species to lose their virulence partially or completely. Cultures of bacteria which have been thus weakened have often been employed for inoculating purposes as a prophylactic measure against infectious diseases.

If the above-mentioned noxious influences are permitted to act too intensely or too long the bacteria will finally die. It is possible to kill bacteria by a great number of chemical substances, the chief of which are our commonly used antiseptics, bichloride of mercury and carbolic acid, provided they are employed in sufficiently concentrated solutions. Bacteria may also be destroyed by insufficient nourishment, by deprivation of water, by exposure to the direct rays of the sun, or by other antagonistic bacteria or the products of their metabolism (acids, alkalies), and especially by abnormally low or high temperatures, ranging from 50° to 80° C. (122° to 176° F.) and higher. As we have said before, low temperatures are less injurious, as a general thing, than abnormally high temperatures. Many of those bacteria which do not form spores, and the majority of the kinds which do, are capable of retaining their vitality in ice. The spores are also very resistant to high grades of temperature, ranging between 50° and 80° C. In general they are killed only at a temperature of 100° C., some of them needing to be subjected to it from two to ten minutes, and others several hours. Budding, sprouting spores are more rapidly killed than those which have not budded. The most effective manner of destroying bacteria is by subjecting them to boiling water or hot steam. Dry heat, at a temperature of 140° to 160° C. (284° to 320° F.), requires three hours to kill bacteria, while boiling water or steam only requires

from five to ten minutes. According to Tassinari, tobacco smoke has a decided bactericidal power.

Tests and Comparisons of the Germicidal Substances.—The efficacy of a germicide is tested by inoculating the bacterial matter previously subjected to its influence upon living animals and observing whether or not infection follows, or fresh moist or dried colonies may be placed upon glass slides, silk threads, grains of sand, etc., and thus brought into contact for a certain length of time with the germicide that is to be tested. The colonies thus treated are then placed in some nutritive medium, such as gelatine or bouillon, and kept at a temperature of 35° C. (77° F.). If chemical substances are to be tested, the glass slides or threads, etc., must first be washed in sterilised distilled water to prevent them from carrying any of the poison into the nutritive gelatine, and consequently restraining the growth of the bacteria. After the cultures have been kept at the proper temperature for several days, and have shown no development of colonies of bacteria, it may be inferred that the previously existing organisms have been killed by the substance in question.

Ordinary Methods of Studying Bacteria.—The methods of bacteriological investigation consist principally in the study of stained preparations under the microscope, in the formation of cultures, and in the inoculation of animals with pure cultures of the different bacteria. The microscopical part of the investigation of bacteria has been greatly advanced by Robert Koch, who showed the necessity of homogeneous immersion and the proper way of using Abbé's condenser or illuminating apparatus. The basic aniline dyes are the best materials for staining both the bacteria and the cell nuclei. We employ aqueous solutions of gentian violet, fuchsin, and especially methylene blue—e. g., thirty centimetres of a concentrated alcoholic solution of methylene blue, one hundred centimetres of water, and twenty drops of one-per-cent. caustic potash, or a solution containing fifteen drops of carbol fuchsin, twenty grammes of distilled water, and eight drops of concentrated alcoholic solution of methylene blue. If it is desired to make a preparation rapidly from a fluid containing bacteria, a drop of the liquid is evaporated upon a cover-glass. The residue is fixed by passing the cover-glass three times through the flame of a Bunsen burner, and then placing it for a few minutes in one of the above-mentioned staining solutions—methylene blue, for example. In case the above alcoholic carbol-fuchsin-methylene-blue solution is used, eight to ten seconds is sufficient. The excess of colouring matter is then washed from the cover-glass with distilled water, the specimen placed upon a slide and examined in the bright light provided by the Abbé condenser, with or without a blender. The importance of the Abbé condenser lies in the fact that it brings into prominence the coloured portions of the stained preparation, especially the nuclei and the bacteria. When unstained objects are to be examined the use of the condenser is to be restricted—i. e., a narrow blender is to be used, and less light allowed to fall upon the slide. In examining with the microscope fluids containing bacteria, it is a good plan to use hollowed-out slides. For the recent methods of staining bacteria I must refer the reader to the text-books of Fränkel, Hueppe, Gunther, Eisenberg, and others.

Culture Methods—The Various Kinds of Culture Media.—By artificia cultures of bacteria, and their subsequent inoculation upon animals, our knowledge of the effects produced by bacteria has been very much advanced. Bacteria are cultivated partly in liquid and partly in solid nutritive media. The vessels for conducting the experiments are exposed to dry heat at a temperature of 160° C., in a sterilising apparatus, for from one to two hours, while the nutritive media are sterilised in advance in a Papin's digester, or by steam, in order to kill the bacteria which may already be existing in them.

The fluid nutritive media (infusion of meat, infusion of hay, milk, urine, blood serum, etc.) are inferior in every respect to the translucent solid media (gelatine, agar-agar). In the liquid media it is possible to watch the growth and multiplication of bacteria by means of "cultures in hanging drops." With the aid of a sterilised platinum wire hook a drop of the sterilised nutritive liquid is placed upon a cover-glass which has just been heated; to the drop is then added a very small amount of the culture. A concave glass slide is sterilised by heat, vaseline placed around the concavity, and the cover-glass laid upon the vaseline circle, with the drop of nutritive liquid dipping into the concavity. The solid nutritive media (gelatine, agar-agar) become fluid at temperatures between 25° and 30° C. and 35° and 40° C., respectively, but solidify rapidly on cooling. If bacteria are planted in the most commonly used nutritive gelatine (bouillon, eight per cent. gelatine, one per cent. peptone, one-half per cent. common salt), which has been heated to a temperature of 30° C. in a test tube, and so liquefied, and if the well-mixed fluid is then poured upon sterilised glass plates or saucers, the bacteria will grow in the rapidly hardening gelatine, and after the lapse of one or two days will form visible separate cultures. The microscope shows that each colony is made up of individuals of the same species. To prevent the colonies from growing too thickly, it is best to dilute the gelatine first infected, and to pour the diluted liquid upon a larger number of glass plates, a portion of the nutritive medium in the first glass being emptied into a second, to which gelatine is then added, and this last fluid is then mixed with more gelatine in still a third glass. All the mixtures are then poured into a little shallow glass dish. The agar mixture, which remains solid up to a temperature of 38° C., is employed for bacteria requiring a temperature higher than 25° C. It is thus possible to make cultures of any desired species of bacteria in a solid medium. The cut surfaces of slices of a boiled potato are also much used as a solid nutritive medium, and distinct colonies can be made to grow upon them by spreading out over the surface of the potato thus prepared a single drop of liquid containing three or four species of bacteria. Under proper conditions every bacterium will then develop into a separate colony. For some bacteria (pus cocci, diphtheria bacilli, tubercle bacilli, Fränkel's pneumococcus) human saliva and sputum furnish a good nutritive medium (Schmidt, Grawitz).

The different species of bacteria require particular kinds of nutritiv media—blood serum, for instance—while other species must have medi which do not contain oxygen. The latter requirement is obtained by a thic layer of gelatine or agar, or by supplanting the air in the culture vessel l hydrogen gas, or by the addition of reducing substances (one to two p

:trose, formate of sodium, pyrocatechin, etc.). A number of known have as yet eluded all attempts at cultivation.

behaviour of the cultures in the nutritive media, such as gelatine or now be watched very exactly. Some species, for example, form masses, others white slimy drops, and r colonies liquefy the gelatine, or de- colonies having a bright red, yellow, colour, etc.

cover-glass placed upon the gelatine essed lightly on the colonies growing surface, and then lifted off, a portion of y will cling to the glass. This cover- paration is then passed three times rough the Bunsen flame, treated with uchsin or gentian violet, washed with l examined under the microscope.

e-point or Stab Cultures.—The needle- tures are especially important (Fig. are made in the following manner: m wire is brought into contact with ticular colony of bacteria, and then nto nutritive gelatine contained in a tube. In the region of the puncture cteristic culture will develop.

r or Streak Cultures.—When a linear ig. 271) is made the gelatine is allowed , so that its surface forms a plane directed towards the sides of the test- over this surface is lightly drawn the wire which carries the bacteria.

urse care must be taken in both the int and linear cultivations that only ular species of bacteria to be investi- troduced.

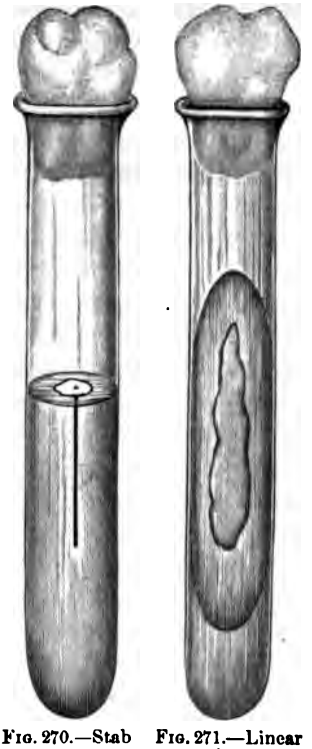


FIG. 270.—Stab or puncture culture. FIG. 271.—Linear culture.

few general remarks on the methods of investigation pursued in gy will suffice for our purpose. More detailed descriptions can be ference to the text-books of C. Fränkel, Flügge, Hueppe, and others. scription of the different bacteria of surgical importance we shall the discussion of certain other questions.

Action of Pathogenic Bacteria—Methods of Transmission, and ntal Inoculation of Animals.—The boundaries between the disease-producing or pathogenic bacteria and the non-patho- not very sharply defined. Even non-pathogenic bacteria r certain conditions, as before remarked, do a great deal of hile, on the other hand, even virulently pathogenic micro- s may in various ways, such as by peculiar methods of culti- e rendered weak or entirely inert (see page 275).

How do the pathogenic bacteria act? The pathogenic bacteria produce their noxious effects, in the first place, by forming specific, extremely poisonous products of metabolism (toxines, see page 267) which damage the animal organism in a definite way. Other species of bacteria become dangerous to the animal economy on account of their great numbers. They increase with great rapidity and spread throughout the body, as is the case with the anthrax bacilli, which in a purely mechanical way produce very serious changes in the different organs, and prove fatal by consuming the nutritive matter, albuminous substances, and oxygen, which are necessary to the life of the organism.

Toxic and Infectious Bacteria.—The first class of bacteria are the toxic, the second are the infectious. The toxic bacteria form their poisons outside of the body only, and are incapable of developing inside the living body. If they gain access in sufficient numbers to poison the body they are carried to all the different organs by the circulating blood, and can be perhaps demonstrated in them here and there; but their presence is of secondary importance, as the main thing is the poison which they have produced, upon the kind and amount of which the disease depends. The animal organism is poisoned by toxic bacteria both from the use of cultures that contain the bacteria and those that are germ-free. The infectious bacteria, on the other hand, possess the power of multiplying within the organism in which they find lodgment, and of spreading themselves through it; and even though very few in number when first introduced, they can increase with incredible rapidity, flooding, as it were, all the organs of the body. The anthrax bacillus is a good example of this variety (see § 77). Schimmelbusch and Ricker were able to demonstrate anthrax bacilli in the internal organs (heart, lungs, liver, spleen, kidneys) in half an hour, and the *Bacillus pyocyaneus* in five minutes after the infection of fresh wounds. Hand in hand with the increase in the number of micro-organisms goes an increased formation of the poisonous products of their metabolism, leading to intoxication (poisoning) of the body. The original infection may be produced by the entrance into the body of an exceedingly small number of microbes. The same species of bacteria may prove infectious for one kind of animal but not for another; but by feeding an animal in a certain way, or by subjecting a particular species of bacteria to proper cultivation, the animal may be rendered susceptible or not to the particular species of bacteria. The glanders bacillus has an exceedingly virulent effect upon field-mice, but white mice are not affected by it. If, however, the white mice are fed upon phloridzin until they become diabetic, they change

and are then susceptible to this bacillus. According to Arloing's statement, the bacilli of malignant œdema become infectious for such animals as are ordinarily not affected by them if the animals, previous to their inoculation, are soaked in a twenty-per-cent. solution of lactic acid, or if their tissues are first treated with pyrogallic or carbolic acids, or bichloride of mercury.

Attenuation of the Virulence of Bacteria.—It has hitherto been impossible to effect a permanent increase in the virulence of the bacteria, or to change the toxic bacteria into the infectious class, or *vice versa;* but, on the other hand, a lasting attenuation and even a total destruction of their virulence is possible, as in the case of the bacilli of chicken cholera and anthrax, the pneumococci, etc. (Pasteur, Toussaint). This attenuation of the virulence of pathogenic bacteria may be brought about in a natural as well as in an artificial way. The natural attenuation will take place, as demonstrated by Flügge's experiments, in such infectious bacteria as are compelled to grow for a long time under conditions differing from those governing their ordinary existence and development, such conditions being represented by artificial nutritive media or atmospheric surroundings to which they are not accustomed. By causing certain bacteria to accommodate themselves to growth upon dead substances—that is, giving them a saprophytic method of life—their capability of developing in the animal organism is lost. A similar loss of specific action can be produced in saprophytic bacteria by cultivating them under altered conditions (Hueppe and others). The virulence of bacteria can also be modified, and even permanently abolished, by subjecting them to various influences which are injurious to them. The poisonous character of anthrax bacilli has thus been rendered weaker or destroyed by cultivation of the organisms in antiseptic or disinfecting nutritive media, such as bouillon containing bichromate of potassium (1 to 2,000–5,000), or anthrax blood containing one per cent. of carbolic acid, or by cultivation under a pressure of eight atmospheres, or by exposure of the culture to the direct rays of the sun. Likewise, by breeding a special species of bacteria several times in animals which are not susceptible to it, the virulence of this species can be diminished. The surest and most usual way of "attenuating their virus" is the cultivation of bacteria in high temperatures; and the lower the temperature that one uses for bringing this about the longer the process of attenuation will take, but it becomes just so much the more permanent, so that the weakened poisonous character of the bacteria is transmitted to their offspring, and in this way it is possible to make a series of completely attenuated cultures. The attenuated differ, in all probability, from

the virulent bacteria in possessing a degenerated protoplasm, a defective vitality, a diminished power of growth, less ability to withstand injurious influences, and especially in having different products of metabolism. Virulent anthrax bacilli, for example, form a greater amount of acid than the attenuated ones. Therefore, bacteria which have been attenuated or weakened do not flourish in the animal system, as they are incapable of overcoming its natural oppositions or hindrances to their growth, and they die relatively quickly either at the point of infection, or in the blood, and especially in the organs where they are deposited by the blood—viz., the liver, spleen, and bone marrow.

Power possessed by the Animal Organism of protecting itself against Bacteria.—The healthy animal or human body possesses various means of protecting itself against the entrance of bacteria. The serum of the blood, particularly if free from cellular elements, has a direct germicidal power, as has been demonstrated by the beautiful experiments of Buchner, Niessen, Stern, and others. This germicidal power of the blood is due to the formation of protective substances (antitoxines) which Buchner and Hahn called alexines. The latter are dissolved albuminous substances which are derived, according to Buchner, from the white blood-corpuscles. The alexines are destroyed as soon as they come in contact with the decomposition products of the bacteria, while, on the other hand, the bacteria themselves are destroyed by the alexines (Buchner and Hahn). It is a fight for life or death, and the stronger wins. The injection of certain fluids into the blood—e. g., nuclein, tuberculin, etc.—causes a marked increase in the number of white blood-corpuscles, and this artificial leucocytosis probably increases the resisting power of the blood against bacteria. The germicidal power of the blood in a given individual appears to have a different intensity at different times. According to H. Buchner, it is dependent also upon the proportion of salts it contains. Fodor says that the germicidal power of the blood is increased as its temperature is raised and as it becomes more alkaline by the addition of alkaline substances. At a temperature of 38° to 40° C. (100.4° to 104° F.) the germicidal action of the blood is greatest, but above 40° C. (104° F.) it rapidly decreases. At all events, it is mainly by chemical processes, if we leave out of consideration the local anatomical peculiarities, that the animal organism protects itself against the entrance of bacteria. Up to a certain point there is also a conflict between the bacterial cells and the cells in the body of the animal. According to Metschnikoff, it is principally the white blood-cells which take up and devour the bacteria (Fig. 272), and for this reason he has called them devouring

cells—phagocytes—and to them he ascribes the most important part in the battle of the system with the bacteria which have entered it. This phagocyte theory of Metschnikoff's has recently been attacked by Flügge, Baumgarten, Weigert, and others. These investigators claim that, contrary to Metschnikoff's idea, the white blood-corpuscles are always the ones that succumb in the conflict with the bacteria if the latter enter the corpuscles in a living condition, and that only dead bacteria are carried away by the body-cells. The new investigations of Buchner and Hahn, however (p. 276), make Metschnikoff's theory more easy to understand. The bacteria are also carried away in the excretions, especially the bile, urine, fæces, and sweat. Cavazzani's claim that bacteria cannot pass through the normal epithelium of the kidney can no longer be maintained since the latest investigations of Biede and Kraus. The latter authorities say that only the salivary and mucous glands and the pancreas do not excrete micro-organisms under normal conditions.

FIG. 272.—Phagocytes (Metschnikoff): *a*, an anthrax bacillus about to enter a white blood-corpuscle; *b*, the anthrax bacillus within the white blood-corpuscle; *c*, white blood-corpuscle with anthrax bacilli which have become broken into pieces.

Natural or Acquired Immunity of Animals and Man towards Bacteria.—The existence of immunity in man or animals towards this or that species of bacteria is a matter of great practical importance. It is in part hereditary and in part artificially acquired. We know that, owing to Jenner's discovery of the last century, man can be made to lose his susceptibility to variola by means of the inoculation with cow-pox virus. The discoveries of Pasteur are in harmony with this important fact—namely, that by inoculation of a weakened bacterial poison the system is rendered non-susceptible to infection by the poison of such diseases as hydrophobia, anthrax, chicken cholera, etc. Though Koch, Löffler, and others have demonstrated, as regards anthrax, that inoculation with the weakened or attenuated anthrax poison provides no certain and absolute protection against this disease, yet scientifically and practically the fact remains established that the animal system can, under certain circumstances, by inoculation with the attenuated bacterial poison, be made unsusceptible to the most virulent substances—in other words, the system becomes artificially immune. This immunity is due probably to the presence of certain antagonistic substances (antitoxines). The active principles of the sub-

[illegible] are probably chemical bodies, [illegible] of the metabolism of the bacteria themselves. Numer[illegible] have been advanced for the explanation of this acquired [illegible] Bacteria. Klein and others hold that it depends upon the fact that during the first invasion a quantity of substances are con[illegible] which are essential to the life of the bacteria in question [illegible]. Charrin claimed on the contrary, that during the first invasion of the bacteria metabolic products (antitoxines) form [illegible], which remain behind and make it impossible for infection to occur [illegible] the same species (retention hypothesis). Metschnikoff [illegible] the phagocytic theory (page 277) for explaining acquired immu[illegible]. [illegible] is probably right in saying that the acquired tolera[illegible] of a person, or immunity, is not a single process, but is brought about now in this way and now in that. It is possible that the exhaus[illegible] or retention hypothesis, or Metschnikoff's cell theory, or the [illegible] action of the blood and tissue fluid, all play an important part. The chief fact to emphasise here is that the human organism, both under normal conditions and in the course of infectious diseases, possesses a powerful means of protection against the invasion and action of bacteria. The specific protective substances or antitoxines are formed during the course of the different infectious diseases in the [illegible] cells of certain organs and are given over by them to the blood (Ehrlich, Wassermann, Wernicke, Pfeiffer, and others). Buchner claims that the antitoxines are formed from the substance of specific bacterial cells.

[illegible] interest attaches to the experiments of Wooldridge, Kitasato, and Behring upon the artificial production of immunity towards an[illegible], tetanus, and diphtheria. Wooldridge discovered that solutions of fibrinogen, after having served as media for the cultivation of an[illegible], made an animal immune to infection from anthrax; but, on the other hand, he obtained this immunity by producing a slight chemical alteration in the fibrinogen, without making use of the anthrax bacilli. Behring and Kitasato made rabbits immune towards tetanus by means of trichloride of iodine. Behring rendered animals unsusceptible to diphtheria by (1) employing cultures which were sterilised or had been treated with trichloride of iodine; (2) by the subcutaneous and intra-abdominal injection of the pleuritic exudate which frequently develops in animals affected by diphtheria; and (3) by the subcutaneous injection of the trichloride of iodine very soon after the diphtheritic infection. The capability of animals for resisting diphtheria was rendered greater by the use of hydrogen peroxide. The blood of such immune animals possesses the power of destroying the poison of the disease,

and consequently their serum has been used for subcutaneous injection in cases of diphtheria with good results. The latest experiences with the antitoxic serum of diphtheria show that the mortality of the cases treated with the serum has become much less. The serum acts the more quickly the earlier it is used in the disease.

The antitoxic method of treatment has also been used in the case of malignant tumours (see Tumours). The tendency at present is to develop this mode of treatment more and more. Certain medicinal substances of vegetable origin also possess immunising properties—e. g., extract of curare is a preventive and curative measure against strychnine-tetanus (Laborde).

Acquired immunity has a very close relationship with the recovery from infectious diseases. The blood or serum of animals which possess a natural immunity from certain diseases will probably be used more and more in the treatment of those diseases in man. Efforts are being made to isolate or, in other words, to produce in a pure state, the antitoxines from the blood and milk of animals made artificially immune. This is particularly desirable, for the reason that after injections of the serum—e. g., of diphtheria—undesirable complications and after-effects are observed which can be ascribed to the animal serum alone. It may perhaps become possible to obtain the antitoxines—e. g., of diphtheria, tuberculosis, etc., in the form of a chemical substance with a definitive dosage, which can be obtained at the druggist's. Brieger and Roux obtained from ten cubic centimetres of diphtheria or tetanus serum about one tenth of a gramme of an easily soluble powder which contained a definite amount of the antitoxine.

The antagonism that exists between many bacteria probably plays an important part in the recovery from infectious diseases. The *Bacillus fluorescens putidus* (Flügge) is, for example, a marked antagonist to pus cocci, the pneumonia bacillus, and the typhoid bacillus, so that implantation of this bacillus in gelatine renders the cultivation of pus cocci, typhoid bacilli, and pneumonia bacilli impossible (Garré). Pawlowsky and Bouchard were able to save from certain death rabbits which had been inoculated with virulent anthrax bacilli, by bringing into the circulation before or after infection large quantities of erysipelas cocci, *Micrococcus prodigiosus*, or the bacilli of greenish blue pus. In other cases a certain affinity is observed between different kinds of bacteria—i. e., one species of bacteria will flourish only after the nutritive soil has been properly prepared by another kind of bacteria (so-called symbiosis of bacteria). In this way weakened bacteria which are in a quiescent condition in the organism can reach a high degree of virulence by the invasion of another species of bacteria (Babes).

Method of Experimental Transmission of Bacteria from Animal to Animal.—Under the heading of pathogenic bacteria which have a specific importance, we class those which are capable of demonstration in all cases of any particular disease, and in no other disease, and are present in such numbers and have such a distribution in the tissues that they readily account for all the symptoms of this particular disease. The certainty of the specific character of a particular species of bacteria is established by its examination under the microscope, artificial cultivation, and inoculation. If an animal dies from a bacterial disease, the post-mortem examination is conducted with the most rigorous asepsis, to prevent the blood and organs of the animal from becoming contaminated with any other bacteria. The skin is washed in a one-tenth-per-cent. solution of bichloride of mercury, and the instruments are sterilised by passing them through the flame of a spirit lamp. After the skin of the animal has been sufficiently removed, the abdominal and thoracic cavities are opened with sterilised instruments which have not before been used, so that no bacteria shall be introduced. Then the organs are examined in the following order: spleen, liver, kidneys, heart, and lungs. Small portions of the blood and spleen, liver and lungs are placed in nutritive fluids, and after the latter have been poured upon culture plates in the usual diluted condition before described, it will be possible to determine whether bacteria are present and of what species they are. Parasitic bacteria which will only grow at body temperatures are cultivated on agar plates kept in a culture oven. The colonies which develop upon the plates are then examined, and it is determined whether there are one or more species present, and which is the most numerous. Then follow the inoculation experiments of the pure cultures upon animals, such as mice, guinea-pigs, rabbits, monkeys, pigeons, and dogs, for the purpose of exciting a disease similar in all respects to the primary one. The inoculation is done by simple subcutaneous puncture, by making an incision and inserting the culture beneath the skin, by placing it in the anterior chamber of the eye, by injecting it into the blood-vessels or into the peritoneal or abdominal cavities, by incorporating the culture in the food, or introducing it with the œsophageal bougie, or by permitting it to be inhaled, as Buchner did, by mixing the culture with sterilised water or bouillon, and then scattering this by means of a spray apparatus as a fine mist containing the bacteria.

Intra-uterine Transmission of Micro-organisms from the Mother to the Fœtus.—The possibility of the transmission of micro-organisms from the mother to the fœtus is of great pathological interest. That pathogenic micro-organisms can pass from the mother to the fœtus has been proved partly

by cases of anthrax infection which have occurred in man, and partly by experiments upon animals (chicken cholera, septicæmia in rabbits, malignant œdema). Birch-Hirschfeld has made a careful microscopic study of the placenta in pregnant goats, rabbits, white mice, and bitches suffering from anthrax, and he found the bacilli in both the placenta and in the fœtal tissues, but in very different amounts in the different animals experimented upon. He affirms that the healthy placenta will not ordinarily permit of the direct passage into the fœtal circulation of either finely divided foreign bodies incapable of increase in numbers, or of micro-organisms; but the placenta, without necessarily undergoing any gross mechanical changes (rupture of the chorionic villi or of the maternal vessels, hæmorrhages), may become pervious from the effects produced by the micro-organisms circulating through it. Micro-organisms, such as the anthrax bacilli, can, when present in vast numbers, penetrate into the fœtal portion of the placenta if assisted by alterations in the tissues forming the walls of the blood sinuses, and by lesions in the epithelium of the villi. These changes can be brought about by the injurious effects due to the growth of the bacteria. (See also § 83, Tuberculosis.)

Non-pathogenic Bacteria.—C. Fränkel gives the following as the principal non-pathogenic bacteria: 1, *Micrococcus prodigiosus*; 2, *Bacillus indicus*; 3, yellow, white, orange, and red sarcinæ; 4, *Bacillus megaterium*; 5, potato bacillus; 6, *Bacillus subtilis*; 7, *Bacillus figurans*; 8, *Bacillus acidi lactici*; 9, *Bacillus butyricus, clostridium butyricus*; 10, bacillus of blue milk; 11, bacteria of drinking-water (*Bacillus violaceus, Bacillus fluorescens*); 12, *Bacillus phosphorescens*; 13, *Bacterium phosphorescens*; 14, *Bacterium termo*; 15, *Proteus vulgaris*; 16, *Bacillus spinosus*; 17, *Spirillum rubrum*; 18, *Spirillum centricum*. For further description of these, reference should be made to the text-books of Flügge, C. Fränkel, and others.

Pathogenic Bacteria.—The pathogenic bacteria are the following: 1, *Bacillus anthracis*; 2, bacillus of malignant œdema; 3, bacillus of pseudo-œdema; 4, bacillus of tuberculosis; 5, bacillus of leprosy; 6, bacillus (?) of syphilis; 7, bacillus of glanders (*Bacillus mallei*); 8, *Comma bacillus* of Asiatic cholera; 9, Finkler-Prior's vibrio; 10, Deneke's vibrio; 11, *Vibrio Metschnikoff*; 12, Emmerich's bacillus; 13, bacillus of typhoid; 14, spirillum of relapsing fever (typhus recurrens); 15, *Plasmodium malariæ*; 16, Friedländer's capsule bacillus; 17, *Fränkel's pneumococcus*; 18, bacillus of diphtheria; 19, bacillus of rhinoscleroma; 20, streptococcus of erysipelas; 21, *Staphylococcus pyogenes aureus*; 22, and *citreus*; 23, and *albus*; 24, *Streptococcus pyogenes*; 25, *Bacillus pyocyaneus*; 26, gonococcus; 27, bacillus of tetanus; 28, bacillus of chicken cholera; 29, bacterium of hæmorrhagic septicæmia (rabbit septicæmia, swine fever); 30, bacillus of swine erysipelas; 31, bacillus of mouse septicæmia; 32, *Micrococcus tetragenus, Bacterium coli commune*, etc.

I shall refer again to the bacteria which are of the most importance from a surgical standpoint under the chapters dealing with the infectious diseases of wounds.

The Mycetozoa and Protozoa.—We must briefly discuss the mycetozoa and protozoa which, according to the latest investigations, also play an im-

portant part in the pathology of man and animals. The mycetozoa or myxomycetes are neither animals nor plants, but a group of living organisms midway between the two, though nearer to the amœbæ, the lowest form of animal life, than to the bacteria, or most elementary plants. The young mycetozoa form slimy masses of protoplasm (plasmodia), changing later into vesicles with an enveloping membrane containing spores, and particularly zoöspores, which move about partly by means of a waving flagellum (Fig. 273, *d*, *e*) and partly by the pushing out and drawing in of protoplasmic processes (Fig. 273, *f*). The zoöspores multiply for many generations by division of the cell into two parts, and finally two or more of these cells join and fuse together, forming again a protoplasmic body, or plasmodium, as it is called. The mycetozoa, the chief representatives of which are myxomycetes and the small group of acrasia, grow upon the decaying parts of plants, algæ, etc.; they are typical saprophytes, though some lead a parasitic life in plants. The plasmodiophora Brassicæ produce a destructive tumour-like disease in the roots of cabbage. The mycetozoa and micro-organisms related to them are also pathogenic for man and animals. Koch surmised this long ago, but it has only recently been proved.

Fig. 273.—*Pl*, young plasmodium from chondrioderma difforme, containing two spores; *a*, ungerminated spore (trichia vera); *b–d*, exit of the zoöspores from the torn spore membrane; *e*, ciliated, *f*, non-ciliated amœboid zoöspores (De Barry).

The Protozoa.—The mycetozoa come next to the protozoa, which are usually looked upon as the lowest forms of animal life, but are not sharply defined from the lowest forms of plants. The protozoa consist partly of a single cell, partly of several similar cells, with a distinct differentiation of their protoplasms. They pass through several stages of development, as exemplified by the amœbæ, which are similar to the white blood-corpuscles, and which multiply by division, beginning with the nucleus.

Leuckart divides the protozoa into rhizopods, sporozoa, and infusoria. The rhizopods consist of unenclosed protoplasmic masses containing vacuoles and a nucleus. They multiply by division, live in solid nutritive media, and move by putting forth finger-like processes (pseudopodia). The sporozoa move about like worms, by expansion and contraction; they multiply by means of spores, and live as parasites; they are nourished by fluids which pass by endosmosis through the cuticular envelope of the cell. The gregarines, living as parasites in insects and worms, belong to the sporozoön class, as do also the oval psorosperms (coccidia, Fig. 274), which lead a parasitic existence in mammals, and the cylindrical psorosperms, found in fishes and amphibia. The infusoria belong to the last division of protozoa; they do not change their shape; they possess cilia and an opening which answers for a mouth, and their protoplasm is made up of a cortical and medullary portion.

It has been proved by recent experiments that both the mycetozoa and protozoa are pathogenic as regards man. Golgi, in Paris (1886), showed that peculiar amœboid bodies were regularly present in the blood during intermittent fever and malaria, and were almost always to be found inside the red blood-corpuscles, in which they underwent lively amœboid movements.

Numerous observers have established the fact that this organism can be demonstrated in the blood in every case of malaria (the *Plasmodium malariæ*). It has hitherto been impossible to cultivate the *Plasmodium malariæ*

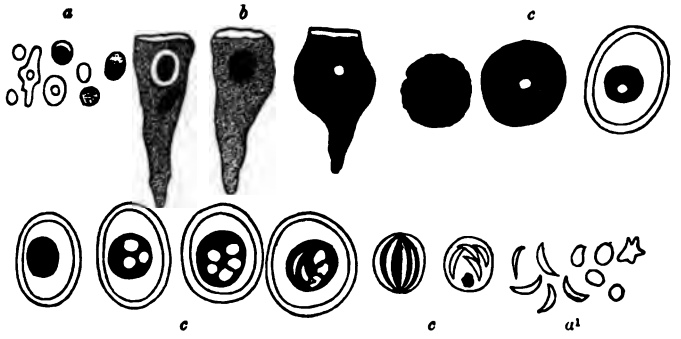


Fig. 274.—Coccidia from the intestine of a mouse; method of intracellular and extracellular development. The oval, circular, or sickle-shaped embryos (spores *a* and *a*¹) wander into the epithelial cells (*b*), where they grow into ripe coccidia with a capsule; these spherical coccidia (*c*) finally break up again into free spores (*a*¹).

artificially, but Celli and Marchiafava have produced malaria in healthy individuals by the intravenous injection of blood taken from malarial patients and containing the plasmodium. This fact does not necessarily prove the pathogenic significance of the *Plasmodium malariæ*, but it has been established beyond a doubt by other experiments that this organism is the real cause of the malarial fever. It has also been proved that some severe forms of dysentery are due to a peculiar amœba (Kartalis, in Virch. Archiv, Bd. 105, p. 521), and molluscum contagiosum to a species of plasmodium. There have also been found mycetozoa and protozoa within the cells in various skin diseases, cutaneous ulcers, and malignant tumours. In fact, sarcoma and carcinoma are probably caused by protozoa (sporozoæ). Among the latest investigations in this direction those of Jürgens deserve especial attention (see Tumours).*

§ 60. **General Remarks concerning Injuries.**—The injuries of the human body are divided into two main groups: injuries with and injuries without interruption of the continuity of the external coverings of the body, including both skin and mucous membrane. The former class we designate as open bleeding injuries, or, in short, as wounds; the latter as bloodless or subcutaneous injuries. This distinction is of the greatest practical importance, since the prognosis of any injury,

* See also Pfeiffer, Die Protozoen als Krankheitserreger.

apart from the influence of the particular portion of the body involved is chiefly dependent upon whether the overlying skin or mucous membrane has been divided or not. Every open wound, be it ever so small—for example, the prick of a needle—may be the cause of an infectious wound disease, and under these circumstances may prove fatal to the patient. It must always be borne in mind, as we have learned in § 59, that the micro-organisms which are everywhere present outside the body may, by their admission to any wound, give rise to the gravest dangers. This cannot occur in subcutaneous injuries where the protecting skin and mucous membrane remain intact and ordinarily prevent the entrance of these noxious bodies into the system. The aim of the modern method of treating wounds is directed, as it should be, towards keeping out of the wound all injurious substances, including bacteria, and towards rendering them innocuous in case they have gained entrance. A probe or a finger which has not been disinfected may cost the patient's life. In the chapter on Fractures we shall see that in the pre-antiseptic periods of surgery the course of subcutaneous fractures was entirely different from that of fractures complicated by wounds of the skin. It was in the treatment of this latter class of injuries that Joseph Lister, the great reformer of modern surgery, began the practical application of his antiseptic or antibacterial method of treating wounds. Now we are enabled to keep a fresh wound free from all injurious substances—in other words, to prevent all infectious wound diseases—and to bring about a cure of a great number of injuries which in the pre-antiseptic days would undoubtedly have proved fatal.

According to the *causation* of the injury, we distinguish between injuries due to mechanical violence and those due to thermal (burning, freezing) or chemical influences (cauterisation). Subcutaneous injuries are produced by blows with blunt instruments, or falls, while open wounds are caused by blows with more or less sharp instruments, and take the form of punctured, lacerated, incised, contused, or gunshot wounds, etc. All wounds due to blows with blunt instruments are more or less contused wounds—that is, the borders of the wounds suffer a more or less extensive crushing or necrosis as a result of the violence used.

The pure incised, stab, and punctured wounds are simple wounds, while the lacerated and contused wounds are, as we shall see, complicated wounds. The condition of the borders and the depth of the wound are matters of great practical importance. If a wound penetrates into a joint or into one of the large cavities of the body, such as the cranial, thoracic, or peritoneal cavities, we call it a penetrating

ound. If a portion of tissue is completely cut or torn from its connections by violence, a wound is formed with loss of substance; but if the portion of tissue still retains some of its connections with the surrounding parts, there results what is called a flap or peel wound. A wound which is clean, not poisoned and not infected, is distinguished from one which is unclean, poisoned, and infected. We count among unclean wounds all those in which there is present any foreign body whatsoever, such as dust, sand, dirt of every description, portions of clothing, bullets, powder grains, etc. Wounds affected with any one of the infectious wound diseases belong to the class of infected wounds (inflammation, suppuration, erysipelas, wound diphtheria, septicæmia, etc.). The wounds produced by bites of snakes, insects, etc., are infected by animal poisons.

The symptomatology and treatment of injuries vary greatly, according to the portion of the body involved and the anatomical peculiarities of the injured tissues. Consequently we divide injuries of the human body into injuries of soft parts, of bones, and of joints, and their symptomatology and treatment will be discussed later on. We shall first give a general outline of the anatomical changes occurring in the healing of a wound.

Railway Injuries.—A very severe and common class of injuries are incurred from collisions between railway trains. Tardieu, Vibert, and others have recorded their valuable experiences on this subject, particularly Vibert, who gave a report of four hundred persons injured in a railway accident at Charenton. The occupants of the train which moves the most rapidly suffer the worst and most numerous injuries. Upon those who die instantly without exhibiting any external injury many punctiform hæmorrhages are found, mostly about the head and upper portions of the body, similar to those which occur in fracture of the base of the skull. Bad fractures and injuries to the soft parts are found chiefly on the lower extremities, unless the victims protect themselves in time by rising from their seats. Not infrequently the lungs are injured (hæmoptysis) by contusion or crushing of the thorax, and there may also be injuries of the abdominal viscera. Very often the patients suffer grave disturbances of the central nervous system—loss of sleep, headache, alterations in their mental condition of a partly excitable, partly melancholic, depressed type, disturbances of digestion, loss of memory, easily excited intellectual fatigue, great susceptibility towards stimulants (alcohol, tobacco), maniacal conditions, auditory disturbances, photophobia, paralysis of accommodation, disturbances of smell and taste, paræsthesia of the sensory nerves, anæsthetic areas, particularly when there is an organic lesion of the brain, muscular tremor, motor weakness, especially in the legs, paralyses, disturbances of circulation and respiration, and increasing cachexia. The patient exhibits, in some cases, every symptom of paralytic dementia. All these nervous phenomena are grouped together under the name of traumatic neuroses. They are particularly liable to make

their appearance after concussion of the brain and spinal cord, and som times are caused by relatively slight accidents. In the majority of cases is a psychosis and neurosis, similar to hysteria, without actual changes in tl central nervous system (Charcot, Strümpell). Albin Hoffmann has correctl pointed out that a traumatic neurosis is of much less frequent occurrence i individuals previously perfectly healthy than has hitherto been supposed; the number of malingerers is large, and is steadily increasing since the accident law went into effect. In the minority of the cases there do occur progressive pathological changes in the central nervous system as a direct result of the accident. The prognosis of these cases is very unfavourable; they often lead to chronic disease of the cortex of the brain: less frequently it is located in the spinal cord. The English physicians have given the name of railway spine to the secondary diseases of the central nervous system following railway accidents. The treatment of traumatic hysteria, or railway spine, belongs to the province of the neurologists.

Dynamite Explosions (i. e., the union of nitro-glycerine with silicic acid in different proportions) give rise to very severe injuries. Owing to the rapidity of the explosion the wounded do not suffer any burns, but the wounds are very red, bleed a good deal, and either resemble incised wounds or they are badly lacerated. Hairy portions of the body have, in consequence of the action of the acid, a white colour, and are not black, as in explosions of powder. The injuries to the bones are extremely severe, the fragments being scattered throughout the body. Pieces of the metacarpal bone have been found, for example, in the thorax, and a torn-off finger-nail in the body of the first vertebra (Rochard). The eyes not infrequently suffer severe secondary disturbances.

§ 61. **The Anatomical Phenomena in the Healing of a Wound.**—The anatomical phenomena manifested in the healing of wounds have been studied chiefly by Thiersch, Gussenbauer, Recklinghausen, Ziegler, Marchand, and others. We distinguish two kinds of repair in a wound: (1) the direct primary agglutination of the divided parts, called healing *per primam intentionem;* and (2) the repair of a wound by the formation of granulation tissue, or, in other words, repair accompanied by suppuration, called healing *per secundam intentionem.*

Healing per Primam Intentionem.—Healing by primary intention takes place in all fresh aseptic wounds, particularly in those produced in the course of an operation, the borders of the latter class (operation wounds) being held by the stitches in continual contact until they adhere together. Those wounds which are treated aseptically heal more rapidly than those treated antiseptically—that is, than the wounds irritated by antiseptic solutions (bichloride, carbolic acid, etc.).

Macroscopic Phenomena in Healing by Primary Intention.—Th macroscopic phenomena manifested in the healing of wounds *per pr mam intentionem* are briefly as follows: We ordinarily find, in tl

first place, that the borders of the wound become agglutinated by a coagulum made up of blood and lymph. During the next four, six, or eight days the union of the wound is definitely established, the coagulum in and around the wound space becoming replaced by new cells and blood-vessels, the former of which gradually change into the fibrillar connective tissue making up the cicatrix. In the case of small wounds, or slight losses of substance, there is usually developed as a result of the coagulation of the blood and lymph a crust, beneath which the complete healing of the wound is accomplished (healing under a scab, see page 180). The skinning over of the wound proceeds from its borders by proliferation of the cells of the rete Malpighii and of the sebaceous glands, if the latter still exist in the surface of the wound. The young cicatrix at first forms a fine red line, which subsequently becomes gradually whiter and softer. The cicatrices of many wounds which unite by primary intention disappear in course of time more or less completely.

Healing by Secondary Intention.—The healing *per secundam intentionem*, with the formation of granulation tissue, takes place in badly contused wounds, or where there has been a loss of substance and it has been impossible to obtain direct adhesion of the divided tissues with the aid of stitches, and also in wounds which have been neglected and not treated aseptically, and in wounds which have been infected by micro-organisms.

Macroscopic Phenomena in the Healing of Wounds by Secondary Intention.—Macroscopically, the phenomena which take place in this form of healing of a wound, involving, for example, vascular soft parts, are somewhat as follows: Until the expiration of about twenty-four hours after the reception of the injury the various tissues exposed in the surface of the wound are clearly distinguishable from one another. Later on the outlines of the various tissues in the wound are obscured by a gelatinous covering, and the wound secretes a reddish-yellow fluid, a mixture of blood serum and lymph. After about two to three days the greyish-red gelatinous wound surface begins to take on a granular, red appearance, and the wound begins to granulate, or to form vascular cellular germinal tissue called granulation tissue, from which there is ordinarily produced an exudate containing a great quantity of round cells—in other words, pus.

In contused wounds with destruction, or rather necrosis, of the tissues, the dead portion of the tissues is first cast off by the process of granulation; the wound "purifies itself." Under these conditions healing without profuse secretion or suppuration is more likely to occur the sooner after the injury the wound is disinfected and dressed aseptically.

The Skinning Over of a Granulating Wound.—The coveri a granulating surface with skin proceeds gradually from tl of the wound, and is accompanied by a simultaneous shrink granulation tissue. If the cutis has not been entirely de there are still traces of the Malpighian stratum present, or thelium of the sebaceous glands is intact, the remains of tl tures will form the starting points within the granulating which skin will spread outwards over the granulating su cicatrices which are accompanied during their formation b tion are thicker, broader, and more unsightly than the si cicatrices resulting from primary union.

All wounds, even those produced in an aseptic operation anc have healed aseptically, contain bacteria. The secretion in the the diminished power of absorption of the latter are, however factors in the prevention of the invasion and further developm teria. Furthermore, we know that the blood, particularly the nishes protection to the organism against bacteria.

Histological Phenomena in the Healing of Wounds.—The *n nomena* which take place in the repair of a wound involv lar tissue is practically the same whether the wound heals with the

FIG. 275.—Wound in the liver (cuneiform excision), twenty-four hours old: *a*, Border of the liver; *b*, blood-clot in the defect. Commencing collection of wandering cells in the borders of the wound.

FIG. 276.—Immigrated white bl in a four-cornered defect in a dead, hardened piece of li which had been implanted precautions in the abdomi rabbit twenty-four hours.

formation of pus or without it. Healing by primary intenti acterised by the formation of a minimum amount of germ

uniting the borders of the wound, while in healing by secondary intention the amount of germinal tissue is much more considerable. After every wound, no matter how free the healing may be from reaction, there follows an inflammation in the sense described in §56, and as a result of this there is a cellular infiltration of the borders of the wound with wandering cells (Fig. 275). This cellular infiltration of the borders of the wound steadily progresses, advancing by degrees into the wound, and taking the place of the blood coagulum which is present (Fig. 276). In cases of pronounced inflammatory infiltration of the borders of the wound the old tissues in the immediate neighbourhood are more or less completely destroyed by fatty degeneration. On about the third day the wound, or the wound cleft, will be found filled with a tissue consisting almost exclusively of round cells, with a very small amount of intermediate substance, while here and there are scattered the remains of the blood coagulum. Later on there will be found large epithelioid cells (Figs. 277, 278), the actual formative cells of the granulation tissue or cicatrix—fibroblasts as they are called—which change into the fibrils of the fibrillar connective tissue (Fig. 278, *a*). I used to believe that these formative cells were direct descendants of the emigrated white blood-corpuscles, but recent discoveries have forced me to abandon this view as incorrect, and I have come to the conclusion that Thiersch, Recklinghausen, and others are right in stating that the original fixed connective-tissue cells and the endothelium of the vessels are the essential factors in the formation of the cicatrix. Ziegler has also recently adopted this view. Nuclei in different stages of division can be demonstrated in the fixed connective-tissue cells and the endothelium of the vessels as they undergo rapid proliferation. The newly formed tissue cells can also become wandering cells. The regenerative pro-

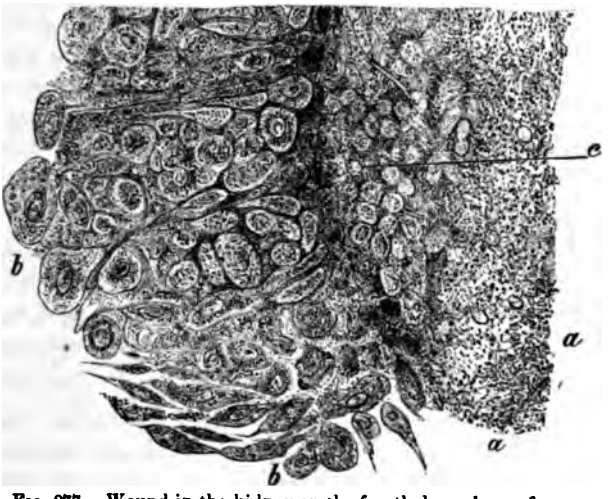


FIG. 277.—Wound in the kidney on the fourth day. Large formative cells, varying in shape (*b*). *a*, Extravasation of blood, with here and there masses of protoplasmic formative material (*c*) produced by a fusion of the white blood-corpuscles.

cesses within the injured organs are likewise carried on by the fixe tissue cells. The connective-tissue cell always gives rise to a ne connective-tissue cell, an epithelial cell to an epithelial cell, but a con nective-tissue cell is never formed from an epithelial cell, or *vice versa*. The leucocytes present either perish—i. e., are either absorbed by the growing tissue cells, particularly the polynuclear leucocytes—or they wander back into the circulation as in inflammation. On the other hand, I believe that some of the protoplasm of the wandering cells is employed as cell material in both the scar formation and the regenerative processes carried on in the original fixed tissue cells. I am unable to say whether the white blood-corpuscles can themselves form fibrillar connective tissue when the circulation is sufficiently active, for example, in a granulating wound; but their importance in this respect is much less than that of the fixed tissue cells—i. e., the cells of the connective tissue and the endothelium of the vessels which have been demonstrated to be the real producers of the scar and are called fibroblasts. Reinke and others believe that further development is possible in those wandering cells which make their appearance after the proliferation of the fixed cells has begun, and which exhibit great vital energy. Ribbert considers it probable that the lymphogenic leucocytes with a single nucleus are capable of taking part in the formation of new connective tissue by helping to cover over the lymph cavities and spaces with endothelium.

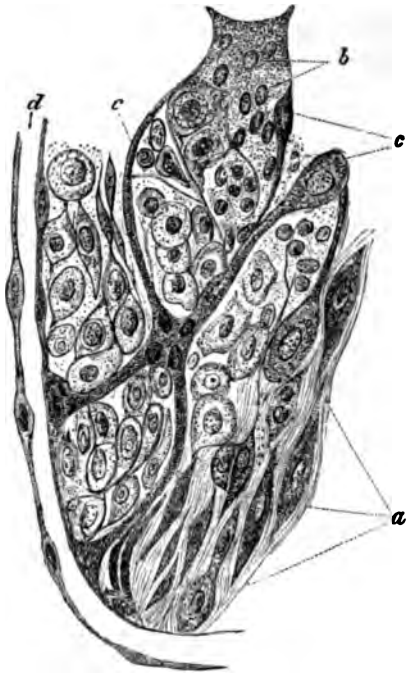


FIG. 278.—Fifth day; a piece of hardened liver with a defect in the middle; large formative cells which have developed from fixed tissue cells; *a*, clearly defined fibrillary connective tissue formed from cells; *b*, masses of protoplasmic formative material with commencing differentiation seen by the appearance of larger nuclei; *c*, solid sprouts from the vessels; *d*, blood-vessel.

New Formation of Tissue according to Ziegler, Marchand, Tillmanns.—Ziegler was the first to make an exhaustive study of the manner in whic new tissue—the fibrillary connective tissue—is formed. He fitted togeth two pieces of glass, about ten to twenty millimetres long and ten millimetr

broad, and made them adherent to each other at the corners with porcelain cement, leaving an empty space, accessible by capillarity from the sides, into which the white blood-corpuscles and the lymphatic fluid could penetrate after the glass plates had been placed beneath the skin or periosteum or inside one of the cavities of the body of an animal. The plates were left in place inside the animal from ten to twenty-five to fifty days, and when removed were gently washed, and then placed for two days in a 0.1-per-cent. solution of hyperosmic acid, after this in spirits of glycerine, and finally in pure glycerine. My own method consists in hardening in absolute alcohol pieces of lung, liver, and kidney, measuring about one cubic centimetre, and making holes and notches in them, and then placing them with every antiseptic precaution in the peritoneal cavity of a rabbit. Sections are afterwards cut from these specimens, and when examined under the microscope will give a very beautiful picture of the new formation of tissues. Ziegler came to the conclusion that the emigrated white blood-corpuscles undergo further development, and form fibrillar connective tissue if there is a sufficient circulation of lymphatic fluid, and especially if enough nutrition is supplied by the development of new vessels. Ziegler has also, like myself, modified this view. We now know that in Ziegler's glass plates, and in my pieces of dead tissue, the new tissue is chiefly developed from the cells of the newly formed vessels. Salzer has also made recent investigations upon the healing up in a wound of foreign bodies, and Marchand particularly has made some very valuable experiments both in the healing in of foreign bodies and in the new formation of tissue. Marchand employed chiefly bits of sponge, cork, elder-wood pith, and pieces of lung and liver injected with blue gelatine, which he buried in the peritoneal cavities of guinea-pigs and rabbits. After four to seven hours a development of a network of fibrin and an emigration of numerous leucocytes took place. After twenty-four to thirty hours, and later, the foreign body became intimately connected with the peritonæum, and within it were found new cell-forms derived from the fixed elements in the neighbourhood, these cells being mostly spindle-shaped, with large, elongated nuclei, though round cells are also present. All these cells spring from the endothelium of the peritonæum, the fixed connective-tissue cells, and the cells of the walls of the vessels, etc., in which the nuclei are seen forming variously shaped figures in the process of their segmentation. There are also present giant cells, often having an extraordinary number of nuclei. The giant cells are formed by the fusing together of fixed tissue cells, and possess the power of absorbing leucocytes; but they exhibit no progressive development, and later on perish by fatty degeneration. Giant cells are only found in those foreign bodies (bits of sponge, elder pith) whose absorption presents difficulties; and Marchand did not discover them in the pieces of lung, as the tissue of which it consists is readily destroyed, and can be absorbed by the leucocytes. The granulation cells are likewise the offspring of the fixed tissue cells, and not of the single or polynucleated leucocytes. Moreover, the offspring of the fixed tissue cells very often become wandering cells. Marchand saw segmentation figures in the nuclei of the mononuclear leucocytes. The polynucleated leucocytes develop from those with a single nucleus, and are retrogressive in nature. The leucocytes take no part in the formation of new tissues, but they do take part in the forma-

tion of fibrin which, according to Marchand, is produced by substances liberated by the death of the white blood-corpuscles. (See also page 297.)

Sherrington and Ballance maintain that the cicatrix is formed from the cells of the plasma, these cells being supplied with nourishment by the protoplasm of the white blood-corpuscles. According to Grawitz, the so-called dormant cells play an important part in repair. These are cells which are previously invisible in the basement substance of the tissues and suddenly become visible—i. e., develop anew when the process of repair begins. The multiplication of these dormant cells gives rise to embryonic germinal tissue, from which the new fibrillary tissue of the scar is formed. (See also page 295.)

The Formation of Fibrillar Connective Tissue.—Ziegler's and my own experiments show that the fibrillar connective tissue—or, in other words, the cicatrix—is formed from the fibroblasts in the following way: The formative cells are at first round, and then enlarge, and look like large, round epithelium; or they are more elongated, or possess one or more processes, some becoming spindle-shaped, others club-shaped; or they may form branching cells or polynuclear giant cells. The processes repeatedly anastomose with one another. The number of the large formative cells then rapidly increases, and in certain localities they lie close together. The fibrillar tissue is formed in part directly from the protoplasm of the formative cells, and is consequently intracellular in its origin, or it comes from a homogeneous intercellular ground substance or stroma which has previously developed from the formative cells. In the intracellular fibre-formation fibres make their appearance on one or both sides of a cell, or at one extremity of it, or in a process, and unite with the fibres of the adjoining cells. The nucleus, together with a portion of the protoplasm of the formative cell, persists as a fixed connective-tissue cell (Figs. 278, *a*, 279). The direction taken by the fibres is usually the same over a considerable area, the formative cells playing no part in determining the direction of the fibres. As illustrated in Fig. 279, the cicatrix is in the beginning rich in large elongated cells, the remains of

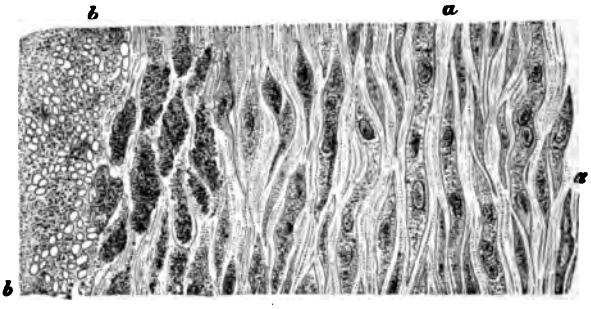


Fig. 279.—Wound in the liver in the stage of cicatrisation, tenth day: *a*, Young cicatricial tissue; *b*, liver tissue which has partially undergone fatty degeneration in the neighbourhood of the cicatrix, and contains many red and white blood-corpuscles.

the earlier formative cells, which in part become changed into fibres. The size of these cellular remains subsequently diminishes, the fibrous tissue becomes thicker, and the cicatrix is complete (Figs. 280, 281, 282).

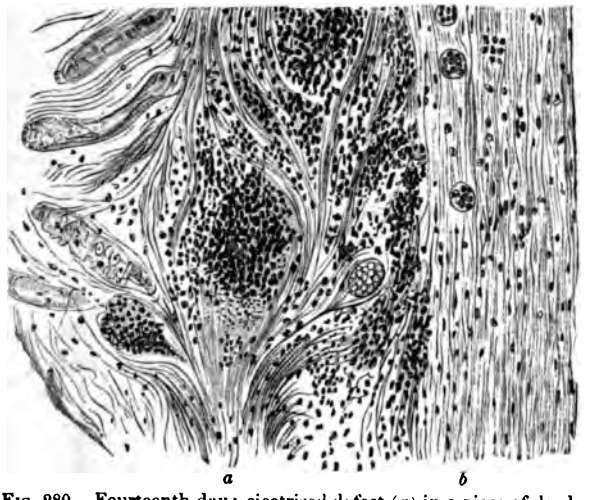


FIG. 280.—Fourteenth day; cicatrised defect (*a*) in a piece of dead, hardened lung (*b*); the latter is filled with numerous wandering and formative cells, especially in the neighbourhood of the defect, or rather the cicatrix.

New Formation of Vessels.—The formation of new vessels proceeds hand in hand with the above-described tissue formation. In fact it is this that renders possible the further development of the accumulated formative cells; and the cells of the newly formed vessels also contribute very essentially to the formation of the new tissue which makes up the cicatrix. In the earliest stages in the repair of a wound, the formative cells, or the cells of the granulation tissue, receive their nutriment

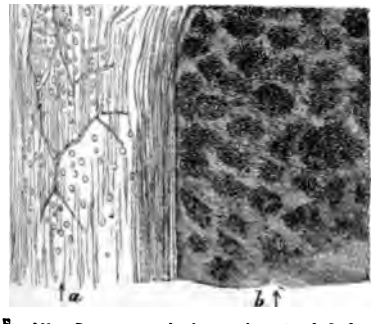


FIG. 281.—Seventeenth day: cicatrised defect (*a*) in a piece of a dead, hardened liver (*b*) implanted within the abdominal cavity of a rabbit.

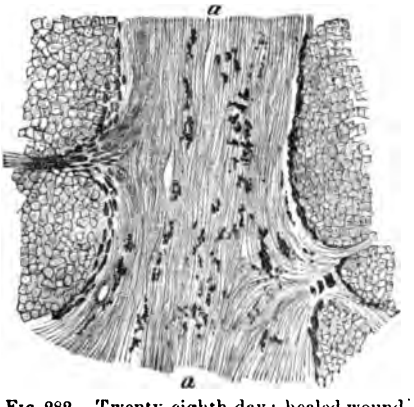


FIG. 282.—Twenty-eighth day; healed wound in the liver, cicatrix (*a*) containing blood pigment.

rom the stream of plasma escaping from the vessels in the neighbourood. As Thiersch has shown, this intercellular circulatory system can e injected through the blood-vessels. But this arrangement for sup-

plying nutrition to the cells is only temporary, and the formation new blood-vessels is required for the further process of repair in wound.

The development of new blood-vessels is the result of an actu sprouting from the walls of pre-existing vessels (Figs. 278, 283, 28 There is first noticed on the external surface of a capillary loop a gra ular accumulation of protoplasm, which gradually enlarges (Fig. 28 *a*, *b*, *c*) and grows into a solid protoplasmic filament, which contains nucleus. This protoplasmic filament, simple (Fig. 283, *f*) or branched (Fig. 283, *d*, *e*, *g*), joins either with the wall of another vessel, or unites with another similar sprout advancing in the opposite direction and springing from another similar capillary loop (Fig. 283

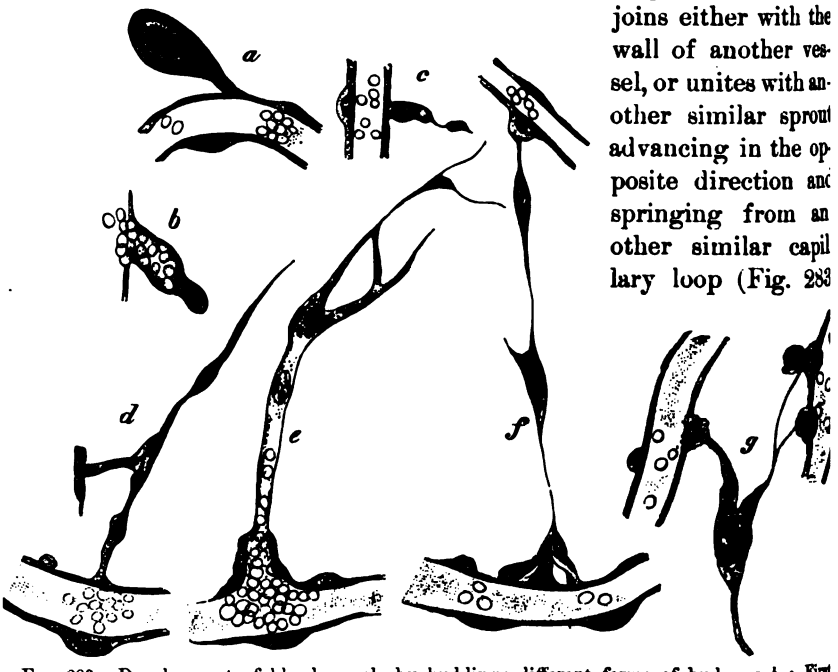


Fig. 283.—Development of blood-vessels by budding; different forms of buds. *a*, *b*, *c*, First stages; *d*, *f*, *g*, simple and branching solid buds; *e*, vascular bud which is being made hollow and which already contains blood-corpuscles.

d, *f*, *g*). There are also formed, not infrequently, protoplasmic filaments which turn back in an arch to the same vessels from which they started. Furthermore, processes from the spindle- or club-shaped or branching formative cells of the intercapillary tissue join with the sprouts from the walls of the vessels, and thus the material in the formative cells helps in the formation of the new blood-vessels. After a certain length of time the originally solid protoplasmic filaments become hollow from liquefaction of their interior, giving rise to open communication with the mother vessels, while the daughter v

sels become more and more hollowed out and gradually filled with blood from the mother vessels. Not infrequently an open pouch (Fig. 283, *b*) develops at the very outset from the wall of the vessel, gradually tapering off into a filament of protoplasm. The walls of the daughter vessel, the newly developed capillary, are at first homogeneous, later on nuclei are added, and they take on a plainly recognisable cellular structure, consisting of flat cells (endothelial cells). Subsequently the walls of the vessel are strengthened materially by the formative cells in the neighbourhood.

FIG. 284.—Development of new blood-vessels by budding. Seventeenth day. Wound in the liver.

The above-mentioned protoplasmic filaments shooting out from the walls of the vessels are made up partly of the cells of the vessel walls, and partly, as I believe I have observed, of white blood-corpuscles which have passed through the capillary wall. At a later period a shrinkage takes place in the newly formed connective tissue of the cicatrix, and a portion of the vessels disappear, causing the original red scar to become pale.

The manner in which the wound, or rather the granulating surface, is covered with skin, has been briefly stated above. For the purpose of healing over large granulating surfaces, Réverdin employed the transplantation of small particles of skin. This method of skin transplantation was, however, first made a useful procedure by Thiersch (see § 42). For a description of the histological changes occurring in the union of transplanted pieces of skin, see page 149.

Reunion of Entirely Severed Portions of the Body.—Parts which have been completely severed from all their connections with the body may again become united in the same manner as the skin grafts of Réverdin and Thiersch. But this is only possible in the case of small portions of tissue, such as the tip of the nose or of the fingers. To these phenomena belong the reposition of teeth which have been extracted,

the transplantation of living or dead bone or cartilage into defects in bone, etc. The success of all these operations is dependent upon the strictest observance of the rules of asepsis. The transplantation of the various tissues above mentioned has been described on page 150.

The Formation of a Cicatrix in a Vessel, or the Organisation of a Thrombus.—The formation of a cicatrix in a vessel which has been wounded or ligated is of special importance.

The following is a brief description of the manner in which the thrombus forms in a vessel: Since Brücke made his famous experiments, we know that the blood is kept fluid within the walls of the vessels because of its contact with a normal endothelium, and because of its constant movement. If either one of these two conditions is lacking, if the integrity of the endothelium of the vessels is altered in any way by an inflammation or traumatism, if the blood escapes from the walls of the vessels, or if its circulation is interrupted—for example, by ligation of the vessel—the blood will then coagulate; it will form a thrombus.

The thrombus which develops after ligation of an artery, for example, extends from the point at which the ligature has been applied to the nearest lateral branch above and below. The same holds true as regards the veins. We know, however, that in a vein extensive thrombi form much more readily than in an artery, and this is the case not only when the lumen is occluded by a ligature or an injury, but also when there occurs a pronounced stasis and obstruction to the return-flow of the blood. If two ligatures are applied to a vessel with a moderate interval between them, the blood will coagulate between these ligatures; but a thrombus does not always develop after the ligation of a vessel. Baumgarten demonstrated that the blood lying between two ligatures may remain fluid for three, four, or even twelve to fifteen days if the ligation is carefully performed, and particularly if the wall of the vessel is not isolated from its connections with the adjoining tissues, and if its nutrition from the vasa vasorum is not interfered with. Under such conditions the endothelium appears to remain intact and performs its functions normally, and consequently the blood, though not moving, retains its fluid character.

In wounds or injuries involving only a portion of the circumference of a vessel there is not always the formation of a thrombus filling the entire lumen of the vessel. The rent in the wall is often completely filled by a thrombus which organises, leaving only a thickening of the vessel at the site of the injury. This method of repair may take place in vessels of any size whatsoever. Again, a thrombus which at the outset only partially fills the lumen may finally cause its total occlusion by the addition to it of one layer of coagulum after another.

We have to deal mainly with thrombi occurring after an injury or the ligation of a vessel. Mention should also be made of the so-called compression thrombi, which form when the blood is brought to a standstill as a result of compression from without, as by tumours; of the dilatation thrombi in aneurysms and varices; of the thrombi caused by inflammatory processes in the walls of the vessels accompanied by destruction of the endothelium, etc.

But changes in the walls of the vessels and primary disturbances in the circulation are not always sufficient in themselves to produce coagulation of the blood; the cause for the thrombosis must be sought for not infrequently in a general alteration in the composition of the blood. Silberman has seen multiple coagula form during life from acute poisoning by the salts of hydrochloric acid, arsenic, phosphorus, and several other blood poisons. On the other hand, Arthus proved that by depriving the blood of its calcium it loses its power of coagulation.

Red, White, and Mixed Thrombi.—There are red, white, and mixed thrombi. The formation of a white thrombus by an accumulation of white blood-cells can be watched under the microscope by irritating with a crystal of common salt placed in its neighbourhood, some large artery or vein lying in the spread-out mesentery or tongue of a curarised frog. At the point of irritation the inner wall of the vessel becomes covered with white blood-corpuscles, and a white immovable plug gradually develops, filling the entire lumen of the vessel by a constant addition of new white corpuscles to those already in place. Some investigators claim that the white thrombi described by Zahn are not formed from white blood-corpuscles, but from the blood plaques discovered by Bizzozero, those very small, delicate, colourless, disk-shaped bodies which constitute the third formed ingredient of the blood. The origin of the blood plaques, which can be stained with methyl violet while in a neutral common-salt solution, is still obscure, and their significance is still a matter of controversy. The average number of plaques in human blood is 245,000 per cubic millimetre. Their number is sometimes increased and sometimes diminished in different diseases. Eberth and Schimmelbusch make a sharp distinction between the white thrombi of blood plaques and the red blood-clots; the blood plaques, according to these authorities, having nothing to do with the formation of fibrin, and simply adhere together at some injured point of the intima as a result of their peripheral location in the blood stream when there is any marked retardation in the flow of the current. They also hold that a thrombus is not identical with a blood coagulum, the thrombi being not red, like the ordinary coagulum, but either entirely, or for the most part, white.

Coagulation of the Blood.—There are many views as to the manner in which coagulation of the blood takes place. Alexander Schmidt and his followers, reasoning from numerous experiments, explain coagulation of the blood in the following manner: The fibrin results from the union of two fibrin generators, the fibrinogen and the paraglobulin, brought about by the action of the fibrin ferment. The fibrinogen exists in solution in the blood plasma; the fibrin ferment and the paraglobulin are first liberated by the disintegration of the white blood-corpuscles, and then have the power of acting upon the fibrinogen. As long as the white blood-corpuscles circulate uninjured in the blood a coagulum cannot form. In the blood of birds and amphibia the disintegrated red (nucleated) corpuscles furnish the fibrin-making substances. The blood in immediate contact with the living and normal walls of a vessel, as we have said, does not coagulate; but if the walls are altered by pathological processes or mechanical injury—if, for example, the intima becomes changed by inflammation, if it becomes roughened, uneven, swollen, torn, etc.—a blood-clot will form at these points even while the cir-

culation still continues. Blood which has escaped from a wounded vessel will immediately coagulate, as will blood within the heart or a vessel after death. Moreover, by the disintegration of white blood-cells which takes place under normal circumstances in healthy, circulating blood, some fibrin ferment develops (Schmidt, Jakowicki, Birk); this is the case especially in venous blood. It is furthermore an interesting fact that in septicæmia and pyæmia the amount of the fibrin ferment resulting from the disintegration of the white blood-corpuscles can be so increased as to give rise to the spontaneous formation of coagula (Köhler and others). On the other hand, fever is produced (Wahl, Bergmann, Angerer) by the absorption of the fibrin ferment from the extravasated blood after operations or subcutaneous injuries (fractures). Hauser, who studied microscopically, by means of Weigert's method of staining fibrin, the formation of the latter in pathologically altered tissues and vessels, also found that the fibrin ferment was formed from degenerating cells (leucocytes, tissue cells, and perhaps also blood plaques and bacterial cells) and the fibrinoplastic materials from its plasma.

Bizzozero, on the other hand, ascribes the formation of fibrin solely to the dissolution of the blood plaques and their derivatives (Zimmermann's corpuscles), and he denies that the white blood-corpuscles have any part in the process. Haym also claims that the cause of the coagulation of the blood when a vessel is injured is to be sought for in what he calls the "hæmatoblasts" (Bizzozero's "blood plaques"). These small, very easily altered cellular elements in the blood become immediately changed, according to Haym, when a foreign body comes into contact with them, or when the intima of the vessel loses its integrity by pathological processes or mechanical influences.

Wooldridge made some very exhaustive experiments upon the subject of coagulation of the blood, under Ludwig's guidance, in the Physiological Institute at Leipsic, and he states that Alexander Schmidt's explanation of coagulation of the blood is correct only to a very limited extent, if at all. Wooldridge disputes the necessity of the co-operation of the formed elements of the blood in the process of coagulation, and asserts that the blood plasma itself, free from all formed elements, contains everything which is necessary for the production of coagulation. The plasma is caused to coagulate by two bodies contained in it, which are a combination or mixture of albumen and lecithin, and are called by Wooldridge A- and B-fibrinogen. He states that certain substances (albuminous bodies containing a very large percentage of lecithin) which have a marked power of producing coagulation can be isolated from the testicle, lymph glands, the chyle, brain, thymus, and stroma of the red blood-corpuscles. He does not attach any importance to the fibrin ferment as a cause of coagulation.

Our knowledge of the coagulation of the blood has been recently enriched by some exceedingly interesting facts discovered by the important investigations made by Marcus Arthus.* Arthus found that by the addition to the blood of oxalate of ammonia—i. e., by decalcification of the blood—the latter loses its power to coagulate; but if chloride of calcium is again added in excess the blood then immediately coagulates. From this it follows that

* Marcus Arthus. Thèses presentées à la faculté des sciences de Paris. Paris: H. Jouve, rue Racine, 15.

the calcium in the blood has a fibrinoplastic action, and that the fibrin ferment and the fibrinogen only act in the presence of calcium salts. Arthus states that the salts of strontium have the same effect as those of calcium, and consequently there is also a strontium fibrin. This makes it necessary for us to recognise many different kinds of fibrin. Arthus maintains that the teachings of Schmidt and Hammerstein should be modified to the extent of making three factors necessary for the coagulation of blood, viz., the fibrin ferment, fibrinogen, and lime salts. The coagulation of the blood may be compared to the coagulation of cheese from milk, the caseine corresponding to the fibrinogen, the curdling ferment to the fibrin ferment, and the cheese to the fibrin. According to Pekelharing, fibrin ferment is itself a calcium compound which is capable of transferring calcium to the fibrinogen, so that the soluble fibrinogen gives rise to an insoluble compound of albumen containing calcium, viz., fibrin.

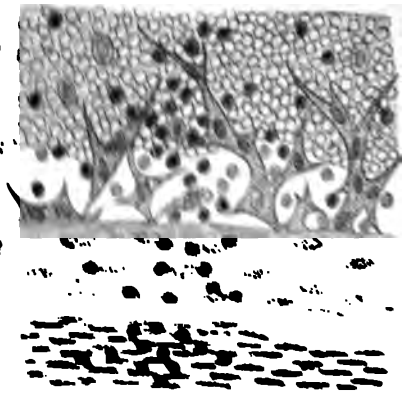
Freund maintains that the coagulation of the blood is brought about by the undissolved phosphate of calcium. The phosphates and potassium salts preponderate in the blood-corpuscles, the sodium and calcium salts in the serum. When the blood comes in contact with a foreign body and ceases to touch the walls of the vessel, the phosphates in the blood-corpuscles unite with the calcium salts in the serum, forming a large amount of phosphate of calcium, which does not all remain in solution.

The Varying Reaction of the Leucocytes to Staining Substances.—The colourless blood-corpuscles (leucocytes) vary in their reaction to staining materials—a matter of great diagnostic importance (Ehrlich). While the nuclei of all leucocytes are coloured by the well-known aniline dyes used for staining nuclei, the protoplasm of the cells behaves differently, possessing for particular dye-stuffs a greater or less affinity. The leucocytes differ also in size and in the number of their nuclei (mono- or polynucleated). The majority of the leucocytes (about seventy per cent. of the colourless blood-corpuscles) form the polynucleated leucocytes, the granules in which are neutral (neutrophilar)—i. e., their protoplasm is only susceptible of being stained by neutral dyes, such as, for example, a neutral mixture of a basic and acid aniline dye (methylene blue and the so-called acid fuchsin). A smaller number of the leucocytes (about five per cent. to eight per cent.) in the blood are eosinophilar or acidophilar cells—in other words, the granules of their protoplasm are capable of being stained bright red by the acid dye eosin. The acidophilar or eosinophilar granules are coarser than the neutrophilar; the cells also are perceptibly larger than the neutrophilar, and for the most part possess one or two nuclei of considerable size. The third class of leucocytes, which are rare—mostly mononucleated cells—possess a protoplasm which is only capable of being stained by basic aniline dyes (basophilar leucocytes). The fourth class of leucocytes, mostly small mononucleated cells with a narrow or broad enveloping band of protoplasm, are partly neutrophilar and partly capable of being stained by acid as well as basic aniline dyes (amphophilar). Mosso* has made an exhaustive study upon the change of the red blood-corpuscles into leucocytes and the necrobiosis of the red blood-corpuscles in coagulation and suppuration.

* Virch. Arch., Bd. 109, 1887.

Changes in the Thrombus.—After a thrombus has formed, the further points in its history which are of interest are (1) its organisation into solid connective tissue containing blood-vessels, or, in other words, the formation of a cicatrix, and (2) the softening of the thrombus. The organisation of the thrombus into connective tissue containing vessels is the most desirable termination; but softening of the thrombus, particularly its suppurative breaking down, brought about by the action of bacteria and accompanied by subsequent embolic processes, is always dreaded by the surgeon. Thanks to the aseptic method of operating and treating wounds, this infectious softening or breaking down of a thrombus is of infrequent occurrence in modern surgery. We shall treat of the infectious softening of thrombi more in detail when we come to diseases of wounds. The calcification of a thrombus from deposition of lime salts is another comparatively satisfactory change which a thrombus may undergo. The so-called phleboliths are calcified thrombi which have formed in veins.

Organisation of a Thrombus and Cicatricial Closure of a Vessel.—We are here concerned with the question of the organisation of the thrombus into connective tissue, and the formation of a cicatrix within a vessel. The minute changes are practically the same as we have described above, and they apply to the arteries as well as the veins. According to Thiersch, Thoma, and others, the closure of a vessel, the so-called organisation of the thrombus, or, more correctly, the substitution for the thrombus of connective tissue, is mainly brought about by a proliferation of the endothelium of the intima. All the authorities agree that the thrombus itself plays no part in the formation of a cicatrix in a vessel; it is gradually [illegible] by the cellular [illegible] which then forms [illegible] connective tissue. At [illegible] by the pro- [illegible] subsequently [illegible] the [illegible] from



›mes steadily stronger, and finally takes the place of the throughout its whole extent. At the conclusion of the pro- only remains of the thrombus nular masses of brown pig- matogenous pigment, proba- ;ide of iron. Simultaneously endothelial proliferation and cells into and throughout the the latter becomes vascular- e formation of new vessels. ıbus does not completely oc- umen of a vessel, its organi- ;s a longer time than when is completely plugged by the Baumgarten). The cicatrix from the cellular germinal ıe manner we have described '88. The vascularisation of bus—i. e., the formation of ls within it—takes its start ›m the point at which the ; been broken or torn. The vasa-vasorum, on account of ıtion of the pressure in the interior of the vessel, grow e relaxed walls into the lumen of the vessel (Benecke, Ack-

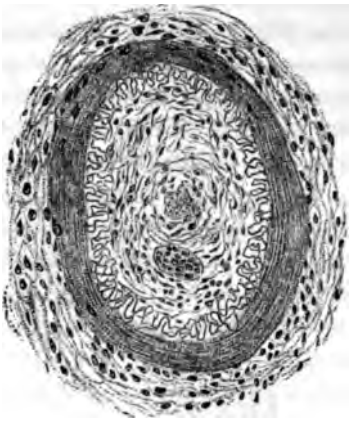


FIG. 286.—Organised vascular thrombus in a piece of dead kidney. Nineteenth day. In the centre are a newly formed blood-vessel and a giant cell. The adventitia of the wall of the vessel contains many leucocytes, but the muscular coat not so many. Gentian, Canada balsam.

ıute changes which take place in the organisation of a thrombus lied very satisfactorily by placing, with every antiseptic precau- ıent of a vessel which has been previously hardened in absolute ide the peritoneal cavity of a rabbit (Seuftleben, Tillmanns). be observed a steadily increasing emigration of colourless blood- nto the wall and interior of the vessel, or rather into the throm- same time there will be a corresponding new formation of vessels rminal cellular tissue, which is developed from the endothelium ly formed vessels and not from the white blood-corpuscles, and thrombus becomes supplanted, in the manner already described, fibrillar connective tissue, and the vessel is closed by a cicatrix

ıgth of time required for the cicatricial closure of a vessel ce by the organisation of a thrombus varies very much. In jects the reparative process is in general more rapid than in luals, and it is slowest in the case of patients afflicted with heromatous) degeneration of the intima of the vessels. In ıich have been experimented upon, vascular tissue will be

found at the site of the thrombus, or rather where the ligature been applied to the vessel, at the end of the second week, and poss even earlier, by the seventh to the eighth day. During the thir the fifth week the cicatrix in the vessel becomes completely forn though in some cases the process takes much longer. In course time the cicatrix in a vessel shrinks like any other scar. If the c trix shrinks in the centre, the scar, or rather the vessel, may ag become pervious, so that the final result may be merely a diminu in the lumen of the vessel, with a thickening of its wall. In still ot cases the cicatrix, as a result of dilatation of the vessel in which it lies, may become perforated by several small isolated vessels con-

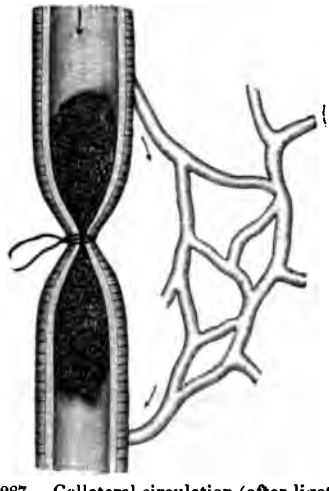


FIG. 287.—Collateral circulation (after ligation of an artery in its continuity) through the central and peripheral branches.

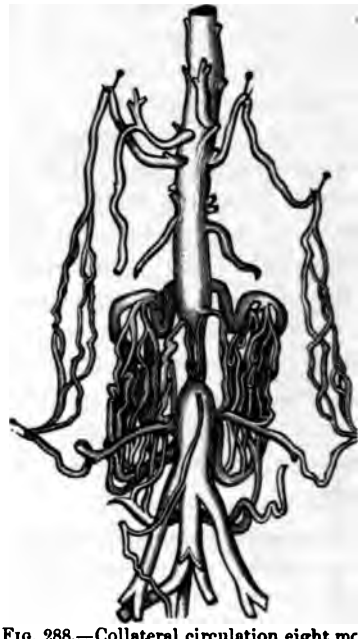


FIG. 288.—Collateral circulation eight mc after ligation of the aorta of a dog (Port

necting the central and peripheral ends of the artery (Fig. 288). so-called sinus degeneration (Rokitansky), in which the thrombu changed into a network of connective-tissue strands having sp between them, is particularly liable to occur in thrombi which dev in veins.

Collateral Circulation.—If a blood-vessel—an artery, for exampl is occluded at some point by a ligature or a thrombus, a collateral culation is immediately developed by dilatation of the vasa-vaso and of the branches given off on the proximal and distal side of thrombus. This restores the circulation, and ensures the nutritio the portion of the body supplied by the occluded artery (Fig. 287).

is interesting to note the manner in which the collateral circulation becomes established after ligation of an artery in its continuity, as illustrated in a specimen obtained by Luigi Porta, showing the collateral circulation eight months after ligation of the abdominal aorta in a dog (Fig. 288).

It is plain that the collateral circulation took place in this instance both through the dilated vasa-vasorum lying between the two stumps of the ligated aorta and the adjacent lumbar arteries, and branches made up partly of old and partly of newly formed vessels.

Recently Nothnagel has made some very exhaustive experiments on rabbits relating to the establishment of the collateral circulation, and he found that six days after applying the ligature there occurred a hypertrophy and hyperplasia of the muscular fibres in the dilated collateral arteries. Nothnagel and Recklinghausen explain the growth of these vessels by the increased rapidity of the blood current within them and the increased amount of nutrition which this brings about. The more blood that passes through a vessel in a given time, the greater is the amount of nutritive material supplied to the wall of the vessel. The pressure theory, which many authorities think sufficient to account for the establishment of a collateral circulation, is, according to Nothnagel, of no value.

The Repair of a Wound in Non-vascular Tissues.—The process of repair in a wound, or the formation of a cicatrix in tissues which do not contain vessels (cornea, cartilage, etc.), is practically the same as for vascular tissue. We know that non-vascular tissues—the cornea, for example—contain an intricate communicating system of canals, in which, under normal conditions, wandering cells are present here and there.

If the cornea is injured there occurs an abundant emigration of white blood-corpuscles from the adjoining sclera and conjunctiva and from the conjunctival sac. The tissue developed from the inflammation—in other words, the cicatrix—is here also formed from the original fixed cells of the cornea.

A cicatrix is formed in cartilage in precisely the same way from the cartilage cells in the neighbourhood. The cicatrix resulting from an aseptic wound—i. e., from one which has healed without reaction—will retain its fibrillar character for a great length of time. Gies claims that it retains this character permanently; but if a severe inflammatory reaction takes place the cicatrix will rapidly become hyaline, like normal hyaline cartilage (see Injuries of Joints).

Regeneration of Injured Tissues.—In every injured organ there is always an attempt to bring about, as far as possible, a complete *restitutio ad integrum.* The regeneration of the damaged tissues will take place the more rapidly and completely the more delicate the cicatrix is—in other words, the stricter the asepsis and the more the wound is

made to heal by primary union without reaction, and the less the ce peculiar to the organ are damaged. But the more highly organis tissues have relatively slight powers of regenerating themselves af they have been damaged. The epidermis, the epithelium of t mucous membranes, bones, cartilage, periosteum, tendons, and oth connective-tissue structures, are capable of regenerating themselve completely, while, on the other hand, losses of substance in the various glands and in muscle are not restored, but their place is supplied solely by scar tissue, in the manner described above. Consequently, a cicatrix which includes the more deeply lying subcutaneous cellular tissue contains no sweat or sebaceous glands and no hair follicles or hairs, and a correspondingly extensive cicatrix in the intestine contains no follicles and no glands of Lieberkühn. Moreover, defects or losses of substance in muscular tissue are only made good, as already stated, by scar tissue, and are not replaced by newly formed muscular fibres; the fibrous cicatrix is interposed like a tendinous intersection in the course of the muscle and enables it to contract. Regeneration of muscular fibre takes place only in the neighbourhood of the cicatrix, and in those cases in which the injury to the muscle has been trifling—a contusion, for example. Ponfick, however, has demonstrated that losses of substance in highly organised tissues, such as the liver and kidneys of animals, can be made good in a relatively brief time by a new development of the tissues characteristic of the organ.

Of the more highly organised tissues the peripheral nerves are exceptional as regards their capability of regenerating themselves. After a nerve has been divided and neurorrhaphy performed, there will often be a complete regeneration of the nerve even when the neurorrhaphy has been performed several months, or even a year, after the reception of the injury. Regeneration has been brought about in a nerve in which there has been a loss of substance several centimetres in length by suturing together the divided ends of the nerve, or by adopting other suitable measures, and now and then even spontaneously. I performed a successful neuroplasty upon the median and ulnar nerves for a loss of substance which they had suffered several months previously (see § 88).

Regeneration of the tissues of the brain and spinal cord never takes place in man, though Brown-Séquard has seen regeneration occur in the divided spinal cord of a pigeon.

The manner in which the different injured tissues—e. g., nerve muscles, bones, etc.—are regenerated under proper treatment will l described more at length when we come to speak of injuries of the tissues (see §§ 87, 88, 101).

Subsequent Pathological Changes in the Cicatrix—Cicatricial Contraction.—*Cicatricial contractures* are the most important of the later pathological changes which scars undergo. The contraction is, of course, proportionate to the size of the defect or the amount of granulation tissue. All cicatrices replacing losses of substance in the skin and the underlying tissues are especially liable to contract. According to the depth to which the loss of substance extends, the cicatricial contracture involves only the skin, or, besides this, the deeper parts, especially the fascia, muscles, and tendons. The cicatricial contractions following extensive burns are especially dreaded. The sequelæ of such contractures vary with the locality which is affected. If one is situated on the flexor aspect of a joint, the latter will become fixed in a certain degree of flexion and cannot be completely extended. Cicatricial shortening of the sterno-mastoid muscle causes wry-neck (caput obstipum); a scar involving the under eyelid will roll the latter outward (ectropion); cicatricial contracture of the cheek will interfere with the opening of the mouth. The chin and neck are sometimes fastened firmly together as a result of burns. This is not the place to describe the treatment for these conditions, and it is only necessary to state that they are now treated with excellent results by methods of gradual extension, or by excision of the scar, followed by implantation of Thiersch skin grafts, or of flaps with pedicles taken, perhaps, from a widely removed portion of the body.

Keloids.—Occasionally the cicatrix becomes the seat of a tumour-like fibrous induration called a keloid. A thick elevation develops at the site of the scar, usually with outgrowths extending into the adjoining healthy tissues. This is really a hypertrophy of the cicatrix. The cause of this keloid, which is rather rare, is not understood. After its extirpation there is usually a recurrence. I saw one case of cicatricial keloid the size of a plum, following a perforation made in the lobule of the ear, which resisted every kind of treatment with the knife and red-hot iron. Sometimes a keloid disappears by degrees spontaneously.

Malignant New Growths.—Occasionally malignant new growths, like carcinomata, may originate in cicatrices. We shall discuss this possibility when we come to the etiology of tumours.

Cicatricial Ulcers.—Now and then cicatricial tissue breaks down and suppurates, giving rise to a cicatricial ulcer, which ordinarily is covered with large fungous granulations having no tendency to become covered with skin. This usually occurs in weak and sometimes in tubercular individuals, and is apt to start from some slight injury, such as the friction produced by clothes might bring about.

Pressure Paralysis of Nerves from Pressure of the Scar.—A large cicatrix may exert injurious pressure upon the blood-vessels in its immediate neighbourhood, and may also cause a pressure paralysis of the nerves. It is well known that these pressure paralyses due to cicatrices have, as a general thing, a favourable prognosis, and will ordinarily quickly disappear with removal of the cause.

§ 62. **The General Reaction which follows an Injury and an Inflammation—Fever.**—The general condition of those who have been injured or operated upon bears a most intimate causal relationship to the be-

haviour of the wound. If the latter heals normally—i. e., aseptically and if no injurious substances gain access from the wound to the circulating fluids of the body, there will usually be no fever. From the fact that a wound which heals aseptically, as a rule, ensures freedom to the patient from a general febrile disturbance, it follows that the febrile disturbance involving the whole system of those who have been injured or operated upon is mainly caused by the absorption from the wound of injurious substances, the most important of which are the micro-organisms and the poisonous products of their metabolism held in solution by the fluids of the body. The so-called wound fever is really an absorption fever—an alteration of the blood.

The fever which accompanies the so-called internal diseases is also in part an absorption fever, and the changes which are present in the blood and produced by the bacteria, or rather the products of their metabolism (toxines), play a most important part in the causation of the phenomenon. Not every fever is, however, of bacterial origin. It may be caused by the absorption of certain injurious materials which are formed without the action of bacteria (see page 313). In the so-called *essential fevers*, on the other hand, we must look for the cause of the fever in the central nervous system. In this latter class belong the febrile disturbances following a violent fright, the periodic stages of excitement in mental disorders, epileptic fits, injuries of the spinal cord, etc. These "nervous fevers" are perhaps caused by an increased metabolism in the tissues due to the excessive nerve irritation, which raises the temperature of the body, or to diminished loss of heat by radiation as a result of the lessened rapidity of the circulation (Murri). The fever which follows phlebotomy and the administration of cocaine is, according to Mosso, also dependent upon the nervous system. Though recent investigations have made the etiology of wound fever so plain to us, we unfortunately are still much in the dark as regards the nature of the febrile process. The symptoms of fever are perfectly simple, but their explanation still presents many insurmountable difficulties, and allows plenty of room for many hypotheses.

We shall confine ourselves to the discussion of the fever which accompanies surgical diseases.

Symptoms of Fever.—The most important manifestations of any fever are (1) the increase in the temperature of the body, (2) the circulatory disturbances, and (3) changes in the metabolism of the body.

The Increase in the Temperature of the Body.—The most constant symptom of fever, and the one which is proportionate to its intensity is the increase in specific heat. For ascertaining the temperature

the body, we use in Germany a thermometer having a scale divided into one hundred parts, and each of the one hundred parts subdivided into ten parts. The most useful is the so-called maximum thermometer, in which the column of mercury maintains its altitude after the instrument has been removed from the axilla or rectum, and readily permits at any time the reading off of the highest temperature registered. The temperature of patients who have been injured or operated upon is ordinarily taken in the axilla or rectum two or three times a day—morning, noon, and evening. But not infrequently it is important that it should be ascertained hourly, or every two hours, especially in cases with high fever, in which the height of the fever decides the kind of therapeutic measures that should be undertaken.

If the fever is slight the temperature in the axilla may amount to 38.5° to 39° C. (101.3° to 102° F.); if severe, to 40° C. (104° F.); while temperatures above 41° C. (104.1° F.) or 42° C. (106.5° F.) are called by Wunderlich hyperpyretic. Unusual rises of temperature like this, to 42° C. (106.5° F.) and higher, are ordinarily the precursors of a rapidly approaching death. Temperatures higher than 44.5° C. (113° F.) are very rarely observed, though Phillipson has recorded the case of a girl twenty-five years old in whom the temperature reached 47.2° C. (116.6° F.). Occasionally the temperature continues rising several hours after the death of the patient (post-mortem rise of temperature). The initial stage of fever is usually characterised by a more or less pronounced feeling of chilliness or a rigour. This is the more pronounced the more rapidly the fever rises and the shorter the initial stage of the fever. A chill is usually absent if the body temperature rises gradually during several days. During the cold stage the temperature of the body is already elevated. The cold feeling is the expression of a nervous excitation caused by the difference in temperature existing between the internal and the external or superficial portions of the body. After the stage of cold there follows the climax —i. e., the fever reaches its maximum point. The subsequent course of the fever varies. The temperature either remains more or less continuously elevated (continuous fever, Fig. 289), or it fluctuates (remittent fever, Fig. 290). If the fever is a continuous one, the difference between the maximum and minimum temperature taken in the course of the day, or morning and evening, will be at the most but a few tenths of a degree (Fig. 289). In a remittent fever there will be a daily fall of about 1° C. (1.8° F.) or more. A third type of fever is the intermittent, in which brief marked rises in temperature alternate with normal or even subnormal temperatures (Fig. 291). After each fall the temperature rises again in the course of the day, regularly

registering higher in the evening than in the morning, or the exacerbations may occur less frequently than this. As we shall see when we come to diseases of wounds, the course of the fever is typical for many

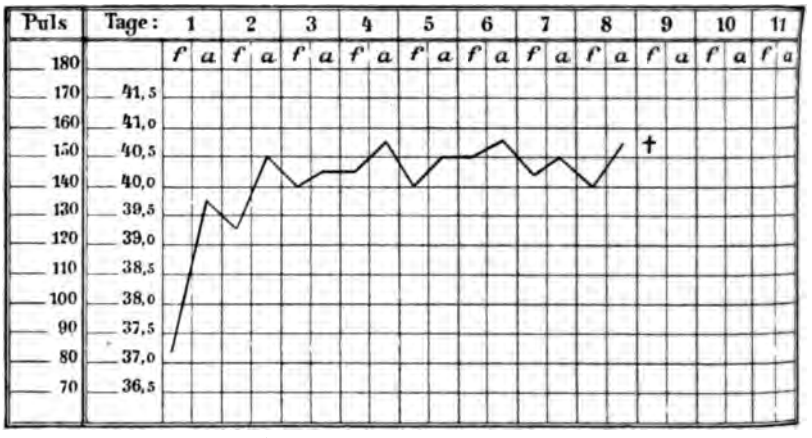


FIG. 289.—Continuous fever. Death on the eighth day.

diseases, especially the way that defervescence takes place. The decline of the temperature may take place rapidly in the form of a crisis, falling 2° to 3° to 4° C. (3.6° to 7.2° F.), and even more in a few hours on a single day (Fig. 291). In such cases the temperature may drop below

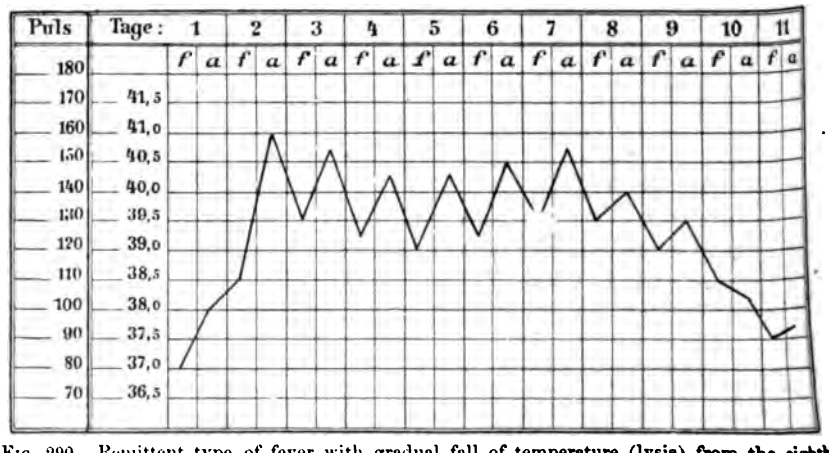


FIG. 290.—Remittent type of fever with gradual fall of temperature (lysis) from the eighth day on.

normal and become subnormal, sometimes accompanied by symptoms of collapse and nervous excitement (delirium of collapse). In other cases the defervescence comes on more gradually (by lysis), being fo

several days continuous or remittent, with transient rises (Fig. 290). The defervescence is usually accompanied by sweating. After the fall in the fever there ensues the stage of convalescence, which is frequently only simulated, as a new outbreak of the fever may take place with a set of symptoms exactly the same as those which occurred in the beginning (Fig. 291). Thus, in a protracted fever like chronic pyæmia, the fever may alternate with an apparent period of convalescence, until death or true convalescence make its appearance. When the fever has a fatal termination, death may come on during the hot stage, and is then often the direct result of the high temperature; or the cause of death is to be sought for in the general weakening of the body brought about by the fever, particularly in the degeneration of

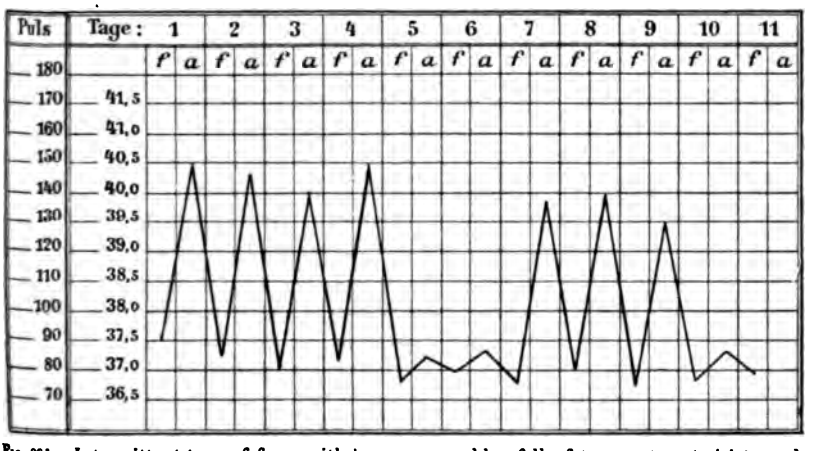


Fig. 291.—Intermittent type of fever with temporary sudden fall of temperature (crisis) on the fifth day; fresh rise of temperature on the seventh day, and then on the tenth day a sudden fall of temperature followed by convalescence.

the muscles of the heart and the muscular coat of the blood-vessels, and, above all, in the general systemic poisoning which is due to bacteria. The behaviour of the temperature curve is a most important diagnostic guide for the surgeon in his estimation of the condition of the reparative process going on in the wound, and it enables him to judge whether the dressing requires changing or not. Moreover, the surgical wound diseases, as we shall see, are characterised by a typical fever curve.

From these facts it is easy to understand the importance of carefully ascertaining the body heat in those who have been operated upon or injured.

The *other symptoms of fever* consist of disturbances of the circulation, the breathing, the digestion, and the nervous system. They occur as the result of the elevated temperature or of the primary disease.

Behaviour of the Pulse in Fever.—Great importance attaches to the condition of the pulse, as regards its frequency, tension, and regularity. Its frequency, in general, corresponds to the height of the fever, but exceptions to this rule are not infrequent; thus, for example, as the result of stimulating the vagus or its centre in the medulla, there occurs a slowing of the pulse with an elevation of the temperature. In cases of iodoform poisoning the temperature may be 38° C. (100.4° F.), while the pulse is very markedly accelerated. The state of the blood pressure is not constant in fever; ordinarily it is somewhat lower than normal (Ludwig, Hüter). If the fever remains high for any great length of time, the blood pressure becomes very decidedly lessened, and may give rise to dangerous symptoms. The pulse is often dicrotic (Fig. 292, 2)—i. e., it shows in the place of a single beat a double one, caused by a diminution of the arterial tension. A dicrotic pulse can be produced artificially in animals by injection of atropine subcutaneously or by administering amyl nitrite by inhalation (Fig. 292, 3). The rapidity with which the blood current flows, according to the measurements taken by Ludwig and Hüter with the sphygmograph, is reduced during fever about one third.

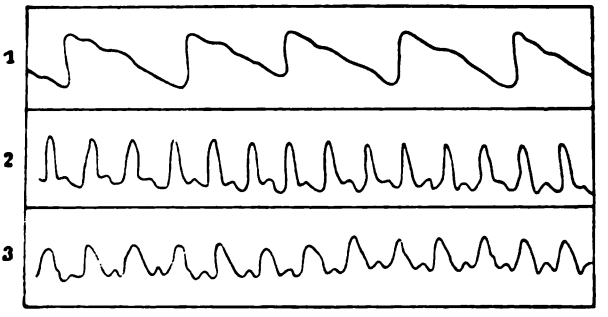


Fig. 292.—1, Normal pulse with well-marked arterial tension; 2, rapid, dicrotic pulse in fever; 3, very rapid dicrotic pulse after injection of atropine (Meuriot-Marey).

Condition of the Vessels during Fever.—Maragliano has demonstrated, with the aid of Mosso's plethysmograph, that the cutaneous blood-vessels are contracted during fever before any rise in temperature can be detected; that, as the contraction of the vessels advances, the temperature begins to rise, and reaches its highest altitude simultaneously with the maximum of contraction in the vessels; and that the fall of temperature is preceded by a dilatation of the blood-vessels.

Cheilo-angioscopy.—Hüter has attempted to make a microscopic investigation of the circulation of the blood in the lip of a man suffering from fever. The cheilo-angioscope, as it is called, which is used for this purpose, is described in Part I of Hüter's Principles of Surgery. By means of this instrument he noted that in fever the circulation in the smaller vessels was retarded, and finally that the blood in them came to a standstill.

Condition of the Respiration during Fever.—During fever the respiration is more active; there is a greater consumption of oxygen, and

as fever increases, or, in other words, metabolism becomes more active, there is a larger amount of carbonic acid produced. According to Kraus, twenty per cent. more oxygen is consumed during fever than when the body is in a normal condition. The respiration, particularly at the beginning of the fever, is deeper than it ordinarily is; but later on, after the fever has persisted some time, it becomes shallower, on account of the weakening of the respiratory muscles. If the fever lasts for a long time, an increase in the amount of gaseous interchange in the lungs may not take place, owing to the accompanying inanition of the patient.

Disturbances of the Nervous System.—The disturbances of the nervous system during fever vary with the height to which the temperature rises, and with the location of the injury. They consist in a feeling of general lassitude and debility, and, if the fever is high, in a dulling of the patient's intellect, accompanied by all kinds of symptoms denoting irritation and depression of the central nervous system.

Digestion.—The *digestion* is impaired during fever; there is pronounced loss of appetite; there is a diminution in the amount of the digestive juices secreted, and the peristalsis of the gastro-intestinal canal is lessened. Thirst is usually increased, and the tongue is apt to be dry.

Urine.—The *amount of urine* secreted is diminished, chiefly as the result of the lessened absorption of nutritive matter and the increased excretion of water by the skin and lungs. The urine of a patient in fever has a high specific gravity; it is rich in nitrogenous substances, particularly urea, and in the calcium salts, and it is poor in sodium chloride. The large percentage of calcium salts and colouring matter is due to the increased disintegration of the red blood-corpuscles which takes place during fever. Not infrequently the urine in fever contains albumen and hyaline casts.

Muscular System.—The *symptoms* referable to the *muscular system*, consisting of weakness and pain, are partly nervous in their nature, being caused, in all probability, by an altered innervation, and partly are directly dependent upon changes in the muscles consisting of a parenchymatous degeneration of their contractile substance.

Body Weight.—The weight of the body diminishes during fever, as a result of the increased metabolism or destruction of albumen. The weight which a patient loses in fever would be much greater if the destruction of fat were in the same ratio as that of albumen. According to Kraus, the fat is not destroyed in the same proportion as the albumen. Leyden has demonstrated by many systematic measurements that the loss of weight is greatest during the crisis of the fever, and in

twenty-four hours at this stage the average weight lost amounts to 1C parts in 1,000.

Prognosis—Outcome of the Fever.—As Cohnheim has correctly stated, the body makes use of fever to destroy as rapidly as possible the noxious substances which have gained access to it. In this sense fever is advantageous to the organism. It was formerly thought that the danger in a febrile disease lay mainly in the elevation of the temperature—in other words, that death was caused principally by the abnormally great specific heat. This view is being more and more successfully contested. We know now, as regards the febrile diseases, especially those following wounds, that the species of pathogenic bacteria which may be present, or the products of their metabolism, are the principal factors in determining the prognosis of the febrile infection. The length of time which a febrile disease lasts may, aside from the severity and nature of the infection, become dangerous to the patient as a result of the increasing inanition. According to Leyden, the daily loss during fever amounts to about seven tenths per cent. of the total weight. Chossat states that all the higher animals die when they have lost forty per cent. of their weight through deprivation of nourishment; consequently a moderately severe fever would be sufficient to kill a man in about eight weeks.

The Pathological Changes during Fever.—The *pathological changes* in fever will be described under the infectious-wound diseases, and when we come to discuss those subjects we shall learn about the changes in the composition of the blood brought about by micro-organisms. It is sufficient to note here that the cloudy swelling, or parenchymatous degeneration, as it is called, of the glands and muscles, varying from a granular cloudiness and swelling to pronounced fatty degeneration, used to be erroneously looked upon as the result of the high temperature. Furthermore, the loss of weight which accompanies a fever of any considerable duration is not the direct result of the fever, but of the infection or intoxication which has occurred. It is more exact to ascribe all these changes not to the increased heat of the body, but to the nature of the infection or poisoning.

Etiology and Nature of Fever, particularly of Wound Fever.—If we would understand the *etiology* and nature of fever, we must attempt to give an explanation of the principal symptom of fever—viz., the rise of temperature. We have already emphasised the fact that fever is mainly the result of absorption. Billroth and C. O. Weber were the first to add materially to our knowledge of the etiology of fever, and they demonstrated that fever can be caused in animals by introducing into the subcutaneous cellular tissue, or directly into the blood, decomposing animal or vegetable matter. But not only are actually decomposing and putrid substances capable of causing fever—i. e. pyrogenous—but also every kind of pus due to bacterial infection including the so-called *pus bonum et laudabile*, has the same pyrogenous effect. The micro-organisms (the bacteria) are the most impo

tant of the causes of fever, giving rise to it as soon as they, or the dissolved poisonous products of their metabolism (toxines), gain access to the circulation (see § 59). The bacteria act by decomposing their nutritive media, consisting of the animal tissues, the blood, and the lymph, giving rise to fermentative and decomposition processes, and destroying the blood-corpuscles, particularly the white ones, etc. We learned in § 59 that the poisonous products of their metabolism which have been isolated from the bacteria are also capable of exciting a general febrile intoxication. Mention should also be made of the rise of temperature occurring in conjunction with constipation, particularly that following an operation, for instance. This fever is probably due to the absorption of soluble decomposing substances which are formed either with or without the co-operation of bacteria. Every intoxication fever is not by any means to be ascribed to bacteria, as we know that substances capable of exciting fever, such as ferments, can be formed in extravasated blood and in the undecomposed secretion of a wound, without the co-operation of bacteria. We are already familiar with several ferments of this kind which have the power of producing fever, notably the fibrin ferment (Alexander Schmidt), which causes a rise of temperature to take place in the animal into which blood has been transfused, particularly when the blood is taken from an animal of another species. Hammerschlag examined the blood of fifteen patients during fever, and found fibrin ferment existing in a free state in the blood of twelve. He also found it free in the blood of two patients who did not have fever. The presence of the fibrin ferment in the blood during fever is not constant, consequently no satisfactory theory of fever based upon the fibrin ferment can be established. In fact, Schmitzler and Ewald have of late denied that the fibrin ferment formed in subcutaneous extravasation of blood can cause fever. They claim that the nucleins and albumoses that develop in these collections of blood are the causes of the so-called aseptic fever. Other investigators have also shown that albumoses of different derivations cause fever. Solutions of hæmoglobin also have a pyrogenous action—i. e., they are capable of exciting fever. Schmiedeberg has isolated from the blood another ferment, histocym, and has demonstrated that this body, which is a product of the normal metabolism, when introduced into the circulation in sufficient quantities can give rise to high fever. Bergmann and Angerer have shown that other ferments, such as pepsine, pancreatine, etc., have the same power.

This non-bacterial ferment fever, as we may call it, is observed after subcutaneous injuries of bones and soft parts which are accompanied by considerable extravasation of blood. This is the explanation of a rise

in temperature, which may reach 39° to 40° C. (102.2° to 104° F.), and which makes its appearance after a subcutaneous fracture, a severe contusion of a joint, or a subcutaneous injury of soft parts. In the same category belongs, perhaps, the fever following absorption of the undecomposed primary secretion of a wound, called aseptic-wound fever, and which may cause the temperature to rise as high as 40° C. (104° F.), even when the repair of the wound runs a perfectly aseptic course (Volkmann and Genzmer). Nevertheless, I believe, at present, that this aseptic-wound fever is often the result of a too free use of antiseptics during the operation. If the wound is much irritated, especially by such an antiseptic as carbolic acid, there will follow, not infrequently, extravasations of blood into the wound, there will be a considerable amount of secretion, and the above-mentioned ferments will develop in the stagnant blood, and, even though the wound remains aseptic, these ferments will give rise to the so-called aseptic-wound fever. Since I began to avoid the poisonous antiseptics in aseptic operations I have not observed this aseptic-wound fever nearly so often. In my opinion this aseptic-wound fever can be explained in different ways—either as a reflex manifestation, or as an absorption fever due to the absorption of certain pyrogenous products (toxines). The latter are chiefly organic substances resulting from the physiological metabolism of the body. Bacterial toxines probably also play a part in some cases.

Chronic Ferment Intoxication.—Langenbeck and Cramer have recorded an interesting case of chronic ferment intoxication with continuous high fever, cough, and occasional diarrhœa in a young woman who had a blood cyst the size of a goose-egg on the thigh. The blood cyst had probably developed from a pre-existing cavernous angioma. After its operative removal all disagreeable symptoms immediately vanished. Within the cyst, as in all blood which is not in contact with the normal walls of the vessels, or which becomes stagnant, there had developed different ferments, among them Schmidt's fibrin ferment, which had then gained access to the general circulation, as the cyst, from the cavernous structure of its walls, was in direct communication with the vascular system. The febrile symptoms, and the coagulation processes in the capillaries of the lungs and intestines, were caused in this way, corresponding in every respect to the facts which had been noted by Köhler, Bergmann, and others in their experiments on ferment intoxication.

We are able, then, to distinguish two classes of absorption fever, the first being the fever caused by micro-organisms and the poisonous products of their metabolism (ptomaines, toxines) which have gained access to the circulation, and the second being the fever which follows the absorption of the disintegrated products of the body, these products

differing but little from the substances formed in the physiological metabolism of the body (non-bacterial ferment fever). These are undoubtedly fever-producing substances whose chemical nature we can at present not exactly determine.

The part played by the nervous system in the production of any one of the various kinds of fevers is briefly spoken of on page 306.

Explanation of the Febrile Process.—How do these fever-producing substances, the bacteria and the products of their metabolism, the non-bacterial ferments, the albumoses, nucleins, etc., and the central nervous system, act? In other words, in what way does the principal symptom of fever, the rise in temperature, come about? It is well known that the body temperature normally regulates itself within moderate fluctuations, and that the amount of heat formed and lost occasionally changes even in health—it increases and diminishes. The amount of heat given off by the body is influenced by the clothing or coverings of the body, by the perspiration, by the circulation of blood in the skin, and, finally, by the increased or diminished excretion of warmth and moisture through the lungs. The amount of heat developed is altered by the voluntary or involuntary increase of muscular activity, by the processes going on in the glands and tissues, by the ingestion of nutritive material, or, in other words, by the increased or diminished supply of fuel. The nervous system, through its reflexes, regulates these various portions of the apparatus, causing each to assume its proper activity, and thus is explained the constancy of the temperature of the body.

During fever the amount of heat produced is, in the first place, increased, and the substances which excite fever must somehow affect those parts of the body which regulate the production of heat. We are ignorant of the exact manner in which this takes place during the febrile process. We can only say that the physiological warmth of the body is the product of the biochemical metabolism of the tissues, and the febrile agent causes an increased metabolism, and consequently an increased production of heat. It can be proved that the metabolism or combustion is actually increased during fever. The increased consumption of oxygen, the increased excretion of carbonic acid and nitrogenous substances, particularly urea, are all evidences of the truth of this. The increase in urea corresponds in general to the severity of the fever, and, according to Cohnheim, no matter how little food is administered, there may be three times more urea excreted than normally, and it may amount to forty to fifty grammes per diem. This increased secretion of urea means that a greater disintegration of albumen is taking place within the body. Leyden gives the excretion of carbonic acid as one and a half to two and a half times more than in a state of health.

Are there certain tissues in which the increased production of heat is more marked than in others? This question has not as yet been answered. We only know that muscular tissue, particularly that of the heart, nerve tissue, and the glands, are important factors in the generation of heat. Mosso was unable to demonstrate in the cortex of a dog's brain any circumscribed centre regulating the heat of the body, but he conjectured that the regulating power was widely distributed throughout the brain and spinal cord. Aron-

son, Sachs, and Gottlieb affirm that the heat centre for rabbits exists in the corpus striatum.

The blood is certainly one of the most important sources of the rise of temperature in fever, and this is particularly true in wound fevers, where it contains bacteria and the dissolved poisonous products of their metabolism. By the latter's presence in the circulation we know that the blood becomes altered and that the white blood-corpuscles are destroyed. It is probable that the increased metabolism and the rise of temperature are the results of the alteration in the blood, since the heart and the walls of the vessels are directly affected by the noxious substances, particularly the dissolved poisonous products of bacterial metabolism. Consequently Bergmann has advanced the view, and it seems to me to be the correct one, that the cause of the febrile rise of temperature is to be sought for in an increased metabolism in the blood. The alterations in the blood, according to Bergmann, are the most essential of all the accompaniments of fever. In order to retain the constancy of the composition of the blood, all the machinery in the body designed for this purpose exhibits a more intense activity, and in this way are explained the increased metabolism and rise in temperature which occur in fever. On account of the elevated temperature of the blood the further development and spread of certain species of pathogenic bacteria are prevented. It is a fact that in anthrax infection, for example, the animal affected has only to be repeatedly cooled off to make the bacilli appear immediately in the blood. The fever or elevation of the temperature of the body and the greater activity of its metabolism is all a conservative process which the body makes use of to more rapidly get rid of the injurious substances which have gained access to it.

In other cases, where there is no intoxication or infection of the blood or tissues, the rise in temperature is due to influences connected with the nervous system, as we have before remarked.

Loss of Heat during Fever.—What are the conditions as regards the amount of heat lost during fever? Ordinarily the amount of heat lost during the chill is less than normal, but during the height of the fever, according to Leyden's measurements, it is greater, being for temperatures above 40° C. (104° F.) double the normal, and even triple when there is an abundant secretion of sweat. Nevertheless the body is unable to get rid of its excess of warmth, because the amount of heat produced is continuously increased during fever, while the amount lost fluctuates, at one time being greater than normal and at another less. The diminution in the amount of heat lost is due to the contraction of the cutaneous blood-vessels, which, as we saw on page 307, begins before the rise in temperature.

Traube, particularly, taught that the cause of fever was to be found in the diminished amount of heat lost, or rather in the pathological changes connected with the loss of heat. It is more correct to ascribe the cause of fever to the increased production of heat resulting from the more active metabolism, in conjunction with a pathological alteration in the amount of heat lost. The amount of heat lost is not constant, as Traube thought, but it is pathologically altered, being at one moment increased and at another decreased. Traube was wrong in denying an increased production of heat in fever.

Definition of the Febrile Process.—If we should wish to formulate a definition of the febrile process, we can say, with Recklinghausen, that fever is a disturbance which increases the metabolism of the materials of the body, especially the tissues which are rich in albuminous substances. This increased metabolism may have its cause in the nervous system or in the blood. Recklinghausen considers that the part of the system principally affected by fever is the motor apparatus of the vascular system, consisting of the heart and muscular coat of the vessels which are regulated by the vasomotor nervous system. The latter plays, according to Recklinghausen, one of the most important parts in the production of fever. The typical symptoms of fever result from a combination of excitation of the nervous and vasomotor apparatus, with an increase in the biochemical processes carried on by the tissues of the body, due to certain causes. The exciting cause of the fever leads to molecular changes in the body substances, but how this comes about still baffles us.

Treatment of Fever.—We shall confine ourselves to the treatment of wound fever. It is mainly surgical, and consists, in the first place, in properly treating the existing injury. The best prophylactic measures in the treatment of wound fever consist in carrying out strictly the rules of antisepsis and asepsis. It is very important to provide for the escape of secretions from the wound by means of careful drainage. If fever makes its appearance in a patient who has been wounded or operated upon, it is advisable to examine the wound carefully to determine whether there is a retention of the secretion or some other abnormity. In wounds which have been sutured, which involve the scalp, for instance, it may be sufficient to remove the sutures and permit a free escape of the retained secretion, and the fever will thus often disappear very promptly. In other cases deep incisions may have to be made on account of the retention of secretions, and abundant drainage may be necessary. I make it a rule to change the dressings on patients who have been injured or operated upon if the temperature rises above 38.5° C. (101.3° F.). If the wound is really aseptic, as in fresh injuries, or after operations, healing without fever is usually assured. The different wound diseases due to infection must receive their special treatment (see §§ 66–82). If the temperature becomes too much elevated, or if the duration of the fever threatens to cause serious weakness of the patient, in addition to the above briefly outlined local treatment of the wound, it is advisable to adopt other suitable means of treating the fever, just as in ordinary febrile diseases. The best way of reducing the temperature when there is no contraindication consists in the employment of cool baths, cold packs, and sponging off with cold water.

The cold-water treatment of fever is considered by many physicians the best means at our disposal for reducing the temperature. It is used either in the form of baths at a temperature of 20° C. (68° F.), in which the patient is immersed for ten minutes, or baths at a temperature of 24° C. (75.2° F.), which are gradually cooled down during fifteen to twenty minutes to a temperature of 22° C. (71.8° F.). At the same time, in proper cases cold water is poured over the patient, or even ice water, as he lies in the tub. This serves as an excellent stimulant to respiration and the psychical functions. The patient is then brought back to bed without being previously dried off, as in this way the cooling off will continue longer. Wine should be administered freely as a stimulant while the patient is being subjected to this treatment. The reduction of temperature by medicaments, such as quinine, digitalis, veratrum viride, sodium salicylate, antipyrine, etc., should be employed when the patient cannot stand cold baths, or when, for some reason or other, their use is not practicable.

The action of the antipyretic drugs, such as antipyrine, has been repeatedly tested in recent times, and it has been proved that they act principally through the nervous system, particularly the vasomotor part of it, and the heat centres in the brain; they increase the amount of heat lost, or they diminish the amount of heat produced, or they do both. Maragliano demonstrated that kairine, antipyrine, thalline, quinine, and salicylate of sodium, whether administered during fever or in health, caused dilatation of the cutaneous vessels, and thus increased the amount of heat lost by radiation.

The pulse must be carefully watched, and, if necessary, the heart's action stimulated by drugs (camphor, digitalis, caffeine, whiskey, etc.). These are to be given early in all those febrile infectious diseases which tend to weaken the heart, such as diphtheria.

The best treatment by the surgeon of wound fever consists in a careful investigation of the wound, and, as far as possible, in remedying any abnormity which may exist. The treatment of the rise in temperature, if present, is next to be considered, though it will generally not be necessary to do more than to rectify any abnormal condition which may be found in the wound. At present antipyresis—i. e., the reduction of elevated temperatures—is not so energetically carried out as it used to be even in medical cases. Lately we have been giving up more and more the idea that the temperature curve is the only consideration which determines our treatment of fevers. Repeated observations have demonstrated that there is no truth in the idea that man cannot survive an elevation of the specific heat of his body above 42° C. (107.6° F.). Strümpell and others have declared that the reduction of

the increased body temperature should not form the only part of our treatment of fevers. A routine treatment of fever is not a good plan. Every case must be treated symptomatically, according to the conditions which may arise. Too energetic antipyresis—i. e., the adoption of too active measures for reducing temperature—can frequently do more harm than good, from the fact which we mentioned before, viz., that the temperature of the body must be higher than normal to render possible the sudden or gradual destruction of many species of bacteria; and if the temperature of the body is lowered, infection of the blood is favoured.

It is wise to give patients who have fever easily digestible food, and to restrict its amount and variety. Cool, effervescing waters with citric acid, fruit juices, and wines should be allowed as drinks. If an individual has been accustomed to the use of alcohol, the latter should not be denied him entirely, as otherwise nervous complications, or even delirium tremens, may make their appearance (see § 64). Furthermore, it is known that alcohol has the power of directly reducing temperature.

§ 63. **Shock.**—By *shock* is understood a peculiar state of depression of the nervous system, which is apt to be excited reflexly by injuries involving a shaking up or contusion of the sensory nerves.

Etiology of Shock.—Fischer, Goltz, and Seabrook consider the essence of shock to be a paralysis of the vasomotor centre in the medulla oblongata, produced reflexly by a contusion or violent disturbance of the sensory nerves in the manner illustrated by Goltz's well-known experiment on the frog. By repeatedly striking the abdomen of a frog there is produced a peculiar state of collapse, which can terminate fatally by cardiac paralysis, the heart stopping in diastole. The cause of these phenomena lies in the fact that by mechanical irritation of the intestines, or the irritation of any sensory nerves, the activity of the brain and, above all, of the vasomotor centre in the medulla oblongata, become reflexly altered, weakened, or paralysed. As a result of this there follows a diminution or paralysis of the vascular tone, particularly in the arteries. There is a weakening in the propelling force driving on the stream of blood, the speed of the current lessens, and the blood pressure diminishes; the blood is unequally distributed, the arterial system is less full, the lungs and brain are anæmic, while, on the other hand, the blood collects in the veins, particularly those of the abdomen. Eventually the disturbances in the circulation may become so pronounced that the heart's action ceases. The inhibitory nerves of the heart play a part only when the terminal branches of the pneumogastric nerves are directly acted upon by the traumatism.

Symptoms of Shock.—The symptoms of shock in man correspond exactly to the facts which have been determined experimentally. All the manifestations of shock can be traced back to the paralysis of the vasomotor nerves produced reflexly by the contusion of the sensory nerves.

The *characteristic symptoms of shock* are a marked pallor and coolness of the skin and visible mucous membranes; the face is without expression; the eyes are dull and staring, the pupils are dilated, and react slowly. The heart's action is plainly delayed, irregular, and weak; the pulse is thready or imperceptible; the respiration is irregular and long; deep breaths alternate with shallow inspiratory efforts. The mind is dull and reacts slowly; the patients are completely apathetic, and will only answer questions tardily and unwillingly. The sensibility of the superficial portions of the body is impaired, and the energy of muscular movement is diminished. Not infrequently there is nausea or actual vomiting. The temperature is about 1° to 1.5° C. (1.8° to 2.7° F.) below the normal. In other cases, instead of the above-described torpid form of shock, there will be a more active set of symptoms—in other words, the patients are more excited, they fling themselves about, cry out, shriek, and act like maniacs.

Shock occasionally changes gradually into deep syncope and ends in death, particularly in the case of neuropathic, anæmic individuals. In such cases there will usually be found complicated injuries with severe loss of blood, and the post-mortem examinations will frequently show that there are also severe internal injuries, perhaps, of the brain. As a general rule, patients suffering from uncomplicated shock will recover after the lapse of a longer or shorter time, ordinarily after a few hours. Sometimes a psychical change persists for a certain length of time, but eventually perfect recovery will take place. All nervous manifestations, syncope, etc., which follow severe losses of blood and which may look very much like shock, should be carefully distinguished from true shock (see §§ 87–89).

The individual symptoms of shock, particularly cerebral shock, will be described in Regional Surgery under Concussion of the Brain. The latter injury may cause the patient to lose more or less completely all recollection of the accident. He may not be able to remember how he was hurt, he may have no idea of distance and time, and may even forget everything he did, saw, or heard for several days before the time of his injury. As the circulation in the brain becomes in time gradually restored and regulated, the patient may recover some of his lost memories, but a part of his experiences, recollections, and conceptions will remain lost forever.

The Treatment of Shock.—The *treatment* of shock consists, in the main, in overcoming as soon as possible the existing paralysis of the vasomotor nerves, together with the accompanying disturbances which the paralysis gives rise to. To combat effectively the cerebral anæmia, the head of the patient should be placed low down; but if venous congestion of the face becomes marked this position of the head must be immediately given up. Fischer and König are right in recommending vigorous stimulation of the skin by sinapisms, electricity, rubbing the extremities, applying dry heat, etc. In fact, Goltz's beating experiment fails if combined with vigorous irritation of the sensory nerves of the extremities. Internally, warm stimulating drinks, strong coffee, hot wine, whiskey, etc., should be administered; there should also be given subcutaneous injections of camphor or calabar extract, digitalin, and atropine. Tincture of digitalis can be tried by mouth instead of subcutaneous injections of digitalin. Dercum has highly recommended the rectal use of a musk emulsion (0.9 to 1.25 gramme), with fifteen drops of the tincture of opium or an enema of strong black coffee. The respiration must be carefully watched, and, if necessary, kept up artificially, as described in § 13. One must avoid undertaking an operation with chloroform narcosis upon a patient in a state of shock. The chloroform narcosis may alone be sufficient to cause the weakly contracting heart to come to a complete standstill. Patients who are suffering from shock should, as a rule, not be operated upon; but if it is absolutely necessary to adopt some operative measures, such as checking hæmorrhage or the like, the operation should be done without chloroform.

§ 64. **Delirium Tremens.**—By *delirium tremens* (drunkard's delirium) is understood an acute outbreak of chronic alcoholic poisoning, which is particularly liable to occur when a habitual drinker is compelled, by some injury or acute internal disease, to remain for some time in bed. Delirium tremens, owing to the increase in the misuse of alcohol, has been observed in youthful subjects, and even in five- to eight-year-old children. These children, whose parents had, as a rule, been addicted to drink, had for a long time been taking daily increasing amounts of alcohol. The delirium usually breaks out very soon after the injury or operation. According to Krukenberg, in about fifty per cent. of the cases there exists, besides the alcohol habit, a tendency to some nervous disease such as epilepsy. Krukenberg, basing his opinion on three hundred and one cases of alcoholism which he observed, among which there were one hundred and sixty-one cases of delirium tremens, denies that the sudden stoppage of alcohol plays a causative part in the production of delirium tremens.

The first *symptoms* manifested are loss of sleep, great restlessness, and constant talking. The trembling movements are characteristic, and particularly evident when the patient is told to hold out his arm or to show his tongue. The patients see animals of every description, and they are very apt to complain that their rest is disturbed by mice, rats, etc., crawling about them. The delirium is generally connected with marked hallucinations, and not infrequently there is pronounced maniacal excitement. They try to get up, and they may even walk about without pain though they have a fracture of the leg. They make frequent attempts to run away, and consequently must be carefully watched. Very often they will have to be put in a strait-jacket and tied in bed. The prognosis of the delirium is in general favourable, though it frequently happens that old people, in particular, die rather suddenly with symptoms of collapse. It must also be borne in mind that the original injury from which such a patient may be suffering—a subcutaneous fracture, for example—may easily run an unfavourable (complicated) course if his violent movements are not carefully enough guarded against, and he is not properly treated. The post-mortem examination will usually reveal the ordinary changes which occur in the organs of drunkards, particularly chronic gastritis, atheromatous degeneration of the arteries, fatty liver, the kidneys of Bright's disease, thickening of the cerebral membranes, etc.

Treatment of Delirium Tremens.—The treatment of delirium tremens consists, in the first place, of vigorous prophylactic measures. It is exceedingly important that the daily amount of alcohol which the patient has been accustomed to should not be stopped, and even more alcohol should be given during his illness than he is accustomed to take normally. In this way an outbreak of delirium tremens can often be avoided. Considerable amounts of alcohol should be administered, best in the form of strong wine or cognac—about one half to three quarters to one litre in twenty-four hours; and, in addition, the patient should be given an easily digestible diet—meat, bouillon with eggs, etc. Furthermore, it is a good plan to administer opium in large doses (0.10 to 0.40 gramme every two hours), with or without combining it with tartar emetic, or opium with chloral hydrate, or morphine subcutaneously, to combat the restlessness and loss of sleep from which the patient suffers. I do not, as a general thing, like these narcotics in the treatment of delirium tremens, and prefer large doses of alcohol, which will often bring on, without the assistance of narcotics, the sleep which is the precursor of a speedy convalescence. I employ opium or morphine only in bad cases of great restlessness or mania. When the latter condition is present, it is an excellent plan to use cold douches,

continued for a considerable length of time, until the patient is put to bed in an exhausted condition. Sawadskje praises the action of strychnine, which he exhibits in doses of 0.003 gramme for a week, to counteract the desire for drink, and as a treatment of the delirium tremens and the conditions which it gives rise to.

§ 65. **Delirium Nervosum and Psychical Disturbances which may follow Injuries and Operations.**—By delirium nervosum is understood a condition of nervous excitement without fever, which is sometimes observed in hysterical persons, following injuries and operations. The delirium may be of the wild, maniacal type, or it may be melancholic. Some cases have the character of hysteria, or senile dementia. The delirium of sepsis, alcoholism, and poisoning from iodoform, morphine, chloroform, and of uræmic states, etc., of course do not belong to this class. Le Dentu has noted over twelve cases of delirium nervosum following operations, and he has collected sixty-eight cases from the literature on the subject, thirty-eight of which were observed after operations on the female genitalia. Delirium nervosum generally makes its appearance two to five days after the operation, and lasts several days or a week, and in exceptional cases may terminate in death. In other rarer cases there are real mental disturbances without delirium nervosum. Advanced age, poor nutrition, previous mental or nervous disturbances, and particularly hysteria, are predisposing factors. In the majority of instances the psychical disturbances occurring in connection with operations upon the male and female sexual organs, or following operations upon the face, etc., are of a transient nature. Mention should also be made of the delirium of collapse, which is occasionally observed after a sudden fall of a high temperature—for instance, after the defervescence in erysipelas, and in hysterical individuals with a subnormal temperature. This delirium of collapse is usually accompanied by transient psychical disturbances. The prognosis of collapse delirium is generally favourable, and the acute mental aberration often disappears in a few days, or even in a few hours. The treatment of delirium nervosum is symptomatic.

§ 66. **The Infectious-Wound Diseases.**—The existence of infectious diseases of wounds has been established beyond a question by the labours of Pasteur, Billroth, Klebs, Eberth, and, above all, by Koch and his followers. Thanks to their careful researches, we now know that the infectious diseases of wounds are caused by micro-organisms, or by the products of their metabolism (ptomaines, toxines). (See § 59.)

Koch, experimenting upon animals, excited infectious-wound diseases which possessed many similarities to corresponding diseases in man. However, the facts which are experimentally ascertained as

regards animals cannot be directly applied to man, as we know that different species of animals are affected differently by the same poisons. A poison or a certain species of bacteria may not be injurious for one kind of animal, while this same poison may immediately excite dangerous symptoms in another. Furthermore, totally different classes of micro-organisms may produce in different animals diseases which are very similar. The bacillus of mouse sepsis is totally different from the bacillus which causes sepsis in rabbits, and it does not cause sepsis in the latter. The sepsis which occurs in mice from infection by a bacillus has only been observed in house-mice, while field-mice are immune from its effects, etc.

Koch was the first to develop an exact method for investigating the infectious diseases of wounds. He introduced improved methods of illuminating and staining preparations, and thus made it possible for us to study the shape, distribution, and number of the bacteria in the body. He, moreover, made cultures of the bacteria which he had found upon solid nutritive media, so as to observe the characteristics of their growth and the immutability of their species. These pure cultures were then reinoculated upon animals, for the purpose of exciting the same disease which they had first caused. We have these exact methods of his to thank for our knowledge of the etiology of the infectious diseases of wounds, and the facts ascertained by experiments upon animals conform very closely to what we have observed in man.

Every inflammation and suppuration of the wound, circumscribed and diffuse cellulitis, acute inflammations of the lymph and blood-vessels (lymphangitis, phlebitis, arteritis), erysipelas, hospital gangrene (wound diphtheria), pyæmia, septicæmia, and tetanus, are all included among the secondary infectious diseases of wounds which may make their appearance in man. These infectious-wound diseases are all caused by bacteria. This class of diseases also includes anthrax, hydrophobia, glanders, etc., which are diseases communicated from animals to man. Actinomycosis, tuberculosis, and syphilis are also due to infection by micro-organisms, and there are still other diseases of a like character which we shall learn about later. The bacteria are capable of gaining access to the tissues or the fluids of the body through any wound, even the smallest interruption in the continuity of the skin or mucous membranes. Schimmelbusch, Ricker, Noetzel, and others in experimenting with animals were able to demonstrate bacteria in the blood ten minutes after infection of a fresh wound. This absorption of bacteria from the wound is, however, usually of no importance to the organism, as it is only the non-pathogenic bacteria that are so quickly absorbed, and not

the pathogenic. During the first four to six hours the infection is only a local one, but after this the further increase in the number of bacteria and their metabolic products brings with it danger to the organism. The bacteria and their metabolic products are attacked and sometimes neutralized by the protective substances (antitoxines) already present in the body or formed by the poisonous action of bacteria. This takes place in the different organs, and particularly in the blood-serum. If the infection is a very virulent one, or if the antitoxines are not present in sufficient amount, death of the individual will be the result. Bacteria cannot enter the circulating blood or lymph through intact granulating wounds or surfaces, and their metabolic products are probably also not absorbed from such wounds. The superficial cellular layer covering the blood-vessels and lymphatics acts like the epidermis, and the secretion of the wound helps in a mechanical way by washing the bacteria from the granulating surface.

As regards the occurrence of infectious diseases of wounds, the local and general predisposition of the individual plays an important part. It is true, however, that little is known of the nature of these anatomical, physiological, or chemical differences that occur in different individuals. The best way of *preventing* an infectious-wound disease is to employ the most careful asepsis or antisepsis in every operation or injury and in the application of every dressing. The possibilities of surgery since the introduction of antiseptic and aseptic methods have increased to a most wonderful degree, and our responsibility towards our patients has become correspondingly greater. Every physician should constantly bear in mind that he may cause the death of his patient by a single transgression of the rules of asepsis—by an unsterilised and non-aseptic instrument, or by an unclean finger. Every fresh wound contains bacteria, and consequently should be thoroughly washed out as soon as possible with some aseptic or antiseptic solution in order to remove the clots which contain bacteria and the other impurities from the wound. It is difficult, and in fact impossible, to kill all the bacteria by means of our antiseptics, but at the same time it is wiser to recommend that the physician in general practice employ antisepsis in injuries rather than asepsis.

The infectious diseases of wounds have, corresponding to the action of the bacteria, partly a local and partly a general systemic character. As was stated in § 62, the general disturbances, the fever, and the general poisoning are caused by the absorption of the metabolic products of the fungi, which, as we shall see when we come to septicæmia, can give rise to systemic poisoning even after they have become separated from the fungi. Their metabolic products thus give rise to an intoxi-

cation which, like every kind of poisoning by chemical substances, cannot be transmitted by inoculation. Infectious diseases caused by the bacteria themselves are, on the contrary, capable of being transmitted from one individual to another. We shall see that each one of the infectious-wound diseases to which man is subject is excited by a specific micro-organism. There are cases, however, which are not due to infection by any single species of bacteria, but are mixed infections—in other words, they are caused by several different species acting together. The questions concerning the significance of the micro-organisms in the causation of the infectious-wound diseases and the various methods for investigating them have been described in § 59.

In all febrile infectious diseases of bacterial origin the cause of the fever is to be ascribed to the changes in the blood brought about by the bacteria, or the poisonous products of their metabolism (toxines). Furthermore, in the fevers due to unformed ferments, or non-bacterial solutions, such as albumoses, nucleins, fibrin ferment, pepsin, trypsin, or hæmoglobin, it is principally, as described in § 62, the change in the composition of the blood which gives rise to the increased oxidation processes going on in the blood, and to the rise of temperature.

§ 67. **Inflammation and Suppuration of a Wound—Etiology.**—Though it was once believed that all suppuration was caused by micro-organisms, we learned on page 241 that Grawitz, De Barry, and others have demonstrated that suppuration can also be excited without bacteria in dogs and rabbits by aseptic (germ-free) chemical substances, such as turpentine, nitrate of silver, mercury, etc. Moreover, sterilised cultures of various micro-organisms, or the sterilised products of their metabolism (cadaverine, putrescine, pentamethylendiamine), have a similar (pyogenic) power of exciting suppuration. When Behring added iodoform to the cadaverine the latter never produced suppuration.

Though it is undoubtedly true that suppuration can be excited by a whole series of germ-free chemical substances, it is just as certain that suppuration is produced in man, under ordinary conditions, by the presence and life of certain distinct micro-organisms, no matter whether the suppuration takes the form of a simple felon, a furuncle, or a dangerous phlegmon. The question does not involve two opposing principles, since the bacteria themselves give rise to suppuration mainly through the chemical products of their metabolism. Ogston, Rosenbach, and others have studied the micro-organisms which are present in acute suppuration, and they have frequently found only a single species, but at other times several. Suppuration in man is mainly due to cocci, which are found either in irregular masses arranged in groups (the staphylococcus, Fig. 293), or in the form of chains (the strepto-

ı, Fig. 296). The streptococcus is more apt to give rise to ling erysipelatous inflammations, the staphylococcus to localised ımation and suppuration, and the latter is the true pus coccus. taken from human subjects with suppurative processes and in- . into mice will, even though it contain no germs, poison mice ıey die within twenty-four hours (Nissen).

ll bacteria found in acute pus foci cause milk to coagulate. That ;ogenic bacteria should cause in some cases only mild suppuration, ı others severe spreading cellulitis that threatens the life of the ıt, and in still others acute osteomyelitis or metastatic pyæmia, is nable partly by the difference in the point of invasion and partly ; variability in the virulence and the number of the micro-organ- It is of interest that the pus microbes act very differently in ic and anaërobic cultures. The pus cocci concerned in a suppura- rocess in the body can often be detected in the blood, urine, and . In exceptional cases the pus in an acute suppurative process ns no bacteria. But this does not prove that they were not pres- first, for we know that there are bacilli which cause suppuration, hen die very soon. Old abscesses frequently contain no patho- bacteria. The lodgment of pus cocci, or rather the starting up ppuration, is favoured by local lesions as well as by weakness of hole organism.

ıe *most Important Pus Microbes.*—1. The *Staphylococcus pyogenes s* (Figs. 293, 294), so designated because of its golden or orange-yellow ing matter, is the species of micro- ; which is most frequently found in ration. (According to Fränkel, it is in eighty per cent. of all the cases ex- d.) These cocci are incapable of mo- ary in size, and are arranged in clus- ften in the form of diplococci. It is ıt in pus, in the air, in dish-water, and earth. The *Staphylococcus pyogenes s* can be grown in pure cultures upon ne, agar-agar, potatoes, and blood- . In gelatine plate cultures, at the f the second day, small punctiform es appear, having a yellow colour and p, slightly depressed border, separat- em from the non-fluid gelatine. Puncture cultures in gelatine at first a dim, greyish point, which after about three days becomes yellowish, ıen orange-coloured; then the gelatine becomes liquefied, and the cul- nks to the bottom. Linear cultures upon agar-agar (Fig. 294) give an ; yellow culture which has a crooked outline. Upon potatoes there ırms a thin, whitish layer, which gradually becomes orange-yellow,

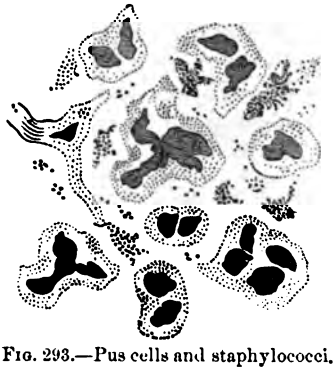


FIG. 293.—Pus cells and staphylococci.

and smells like paste. The *Staphylococcus pyogenes aureus* grows : serum in the same way as upon agar-agar. All cultures develo rapidly—particularly at temperatures between 30° and 37° C. (98.6° more slowly at ordinary room temperatures. They have not hithe seen to form spores. This coccus possesses great of retaining its vitality, and is exceedingly resis instance, to drying, chemical substances, and water. To the latter it has to be subjected for minutes before it is killed. The *Staphylococc genes aureus* can exist a great while without pheric air, is facultative aërobic, and gives rise formation of no gas or foul decomposition; i nises albumen and liquefies gelatine. Gram's is excellent for staining the *Staphylococcus p aureus.*

FIG. 294.—Linear culture in agar-agar—*Staphylococcus pyogenes aureus.*

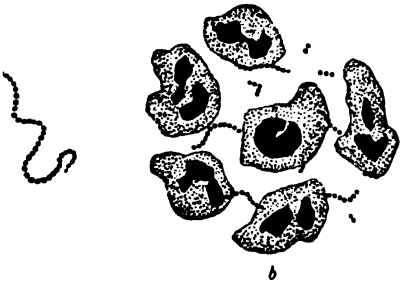
The pathogenic effect of the *Staphylococc genes aureus*, when used experimentally upon varies with the manner in which it is emplo the kind of culture used. Cultures in large can sometimes be injected into the peritoneal without causing peritonitis (Baumgarten, Bu Inoculations have been made upon man by va perimenters. Garré inoculated himself by ins pure culture in a small wound at the root of hi nail, and obtained an extensive suppuration; bing a great number of the cocci upon the heal broken skin of his forearm he produced a large cle. Subcutaneous inoculations in mice, gui and rabbits are without any result, though subcu injections in the two latter classes of animals to the formation of abscesses. Injections made peritoneal cavity usually cause a violent suppur flammation, which kills the animal in a few da jections of the cocci into the blood-vessels giv inflammations of joints and to diseases of the and metastatic abscesses develop in the muscl heart and in the kidneys. If the valves of t are first wounded, a typical endocarditis ulcero If, before injecting the cocci into a blood-vess cutaneous fracture or crush of one of the long hollow bones is ar produced, the point at which the injury is situated becomes "predi to suppurative inflammation of the medullary portion and periosteu *Staphylococcus pyogenes aureus* is the most frequent excitant osteomyelitis (see § 104). Frequently the *Staphylococcus pyogene* is found combined with other micro-organisms in cases of suppurati toxines of the staphylococcus act very differently in different anim the heart, respiration, and nervous system. The leucocytes are destroyed by a poison to which Velde gave the name of leucocidin. ing to Bail, this is formed by various other bacteria.

e *Staphylococcus pyogenes albus* is in all respects similar to the ›coccus *pyogenes aureus*, except in not having the latter's yellow ; matter. It also appears to be somewhat less harmful, and is ›equent occurrence than the aureus. It has been › cause hæmorrhagic purpura of the skin (Silverstein, tc.).

e *Staphylococcus pyogenes citreus* was discovered , and is seldom found in suppurative processes in ıe *Staphylococcus pyogenes citreus* is distinguished ıutiful lemon-yellow pigment (Fig. 267), but is other- :tly like the aureus and albus, except that it takes liquefy gelatine.

tococcus Pyogenes.—4. The *Streptococcus pyogenes* plays a very important part in the causation of sup- It is frequently found alone in abscesses, rarely nation with the staphylococci. This coccus causes, ıost part, progressive suppuration, and from recent ›s is identical with Fehleisen's streptococcus of ery- In the latter disease the streptococcus is found prin- ı the lymph channels of the skin. The streptococci ins generally consisting of six to ten to twenty cocci in a row like links, though there may be hundreds cocci, or links, in a single chain. The chains are de up of two parts, or they may be twisted together nasses, or arranged in slender bundles. The follow- ıe principal facts as regards the development of pure Gelatine plate cultures take the form of fine, round, dots. Linear cultures upon gelatine plates are thickest at the centre e, of a faint brown colour, with the edges of the line plainly punc- later becoming graded off in terraces. Puncture, or stab cultures, in gelatine, have a delicate areola at the point where the puncture enters the gelatine, the line of puncture itself being finely granular (Fig. 295). The streptococcus does not multiply upon potatoes, though some individual cocci increase in size, and, when examined by the microscope, chains are seen made up of some large and some small cocci or links. The *Streptococcus pyogenes* grows best

Fig. 295.—Stab or puncture culture of *Streptococcus pyogenes.*



a, Streptococcus, × 950; b, pus with streptococcus.

erature of 35° to 37° C. (98.6° F.), ordinary room temperatures being ırable to them. The cultures grow slowly, linear cultures requiring ›ee weeks to spread a couple of millimetres. After the lapse of four he cultures will be found, for the most part, to have perished. is not liquefied; it decomposes albumen in a vacuum; it is fac-

ultative aërobic, and is not particularly affected by the absence of oxygen. It is best stained by Gram's method. The *Streptococcus pyogenes* can be found almost anywhere, and its pathogenic effects may be manifested in various ways, according to the manner and the region in which it gains access to the body. It is found in saliva, nasal and vaginal mucus, and in the urethra of man in health. It is often found in tissues which have undergone morbid changes—for example, in typhoid fever, pneumonia, tuberculosis, pleurisy, and scarlet fever, and under such conditions it may give rise to severe inflammatory complications. By itself it causes inflammatory processes and suppuration, which often lead to septicæmia, and are characterised by a marked tendency to extension along the surface. It is a frequent excitant of puerperal fever. Upon the valves of the heart it excites typical endocarditis. When growing in the lymph channels of the skin and mucous membranes it causes cutaneous erysipelas and destructive inflammation of the mucous membranes, and when lodged in the subcutaneous tissue it gives rise to cellulitis, etc. The streptococcus produces fatal toxines, particularly if air is excluded (Roger). Antistreptococcus serum has been successfully used in a number of cases of streptococcus infection—e. g., peritonitis, puerperal fever, and erysipelas. In other cases the results have been negative, and I doubt whether its practical value has yet been proved.

Bacillus Pyocyaneus.—The *Bacillus pyocyaneus*, or the bacillus of green or blue pus, occurs in different forms—e. g., as the *Bacillus pyocyaneus* α Gessard or *pyofluorescens*, and as *Bacillus pyocyaneus* β Ernst. It is a small slender rod (Fig. 297), and is found in the air, earth, and water, as well as in the tissues and fluids of man and different animals. This bacillus gives a blue or green colour to pus and the dressings without causing any complication in the healing process. It is similar to the bacillus of blue milk, but is somewhat narrower. It is capable of very active movements, and is frequently found in the form of bands with four to six joints, and less frequently in the form of long filaments. According to Schimmelbusch, it forms not only green or blue pigment, but also brown and all the gradations between green and brown. The pigment formation depends upon the amount of air, the proper nutritive medium, and upon the condition of the bacilli. The latter may lose their power of forming pigment in both an artificial and a natural way. When cultivated on gelatine plates small white points are formed within the gelatine, then come to the surface, and spread out. The culture medium takes on early a green fluorescent colour for some distance around the cultures, and by the fifth day the gelatine has become completely liquefied. In a test tube the bacillus develops almost exclusively in the deeper parts of a stab culture. The gelatine becomes rapidly liquefied, and assumes a beautiful green colour. Upon agar-agar there forms a moist, rather thick yellow covering, which colours the nutritive medium green. Upon potatoes there is developed a dirty yellowish-green scum, with a green discolouration of the adjoining parts. The colouring matter (pyocyanine) is for the most part seen at the free borders of the clusters, and, according to Ledderhose, is an aromatic crystalline compound having a

Fig. 297.—Bacilli of greenish-blue pus. × 700.

pathogenic properties. According to C. Fränkel, the colouring matter is white when first formed from the bacteria, only assuming its peculiar tinge when brought in contact with the oxygen of the air. The bacilli themselves, and the products of their metabolism, are undoubtedly injurious to animals. If about one cubic centimetre of a fresh bouillon culture is injected into the subcutaneous tissue of a guinea-pig or rabbit there will result a rapidly spreading œdema and suppurative inflammation, causing the death of the animal in a short time. The bacilli will be found at the point of inoculation, in the blood, and in the internal organs. According to Schimmelbusch, the *Bacillus pyocyaneus* exerts a poisonous local and general action, but it does not possess in general the properties of an active pathogenic micro-organism. In rare cases general infections with the *Bacillus pyocyaneus* do occur (typhoid condition, enlargement of the spleen, hæmorrhages from rupture of the weakened blood-vessels, gangrenous ecthyma pustules, etc.). Bouchard and Charrin have demonstrated the very interesting fact that it is possible, with the aid of the *Bacillus pyocyaneus*, to check an advancing anthrax infection and to cause it entirely to disappear. The injection of the toxines of the pyocyaneus has an antipyretic action causing the body-temperature to fall (Langlois and Charrin).

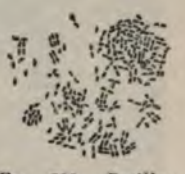


FIG. 298.—*Bacillus pyogenes fœtidus* (Passet). × 700.

Bacillus Pyocyaneus β Ernst.—Ernst has described a variety of the *Bacillus pyocyaneus* as the *β Bacillus pyocyaneus*. It forms a blue colouring matter, or rather blue pus, while the other (*a*) bacillus forms the green pigment. Ledderhose has designated the *a* bacillus *Bacillus pyofluorescens* and the *β* bacillus *Bacillus pyocyaneus β*. Generally the two kinds of bacilli occur together and produce a mixed colour.

Other Colouring Matters Produced by Bacillus Pyocyaneus.—Schimmelbusch states that the *Bacillus pyocyaneus* forms, in addition to the green or blue colouring matter, brown and a whole series of colouring matters ranging all the way from brown to green. The production of the colouring depends upon the presence of sufficient air, proper nutritive media, and upon the structure of the bacilli. The latter may assume different forms in different nutritive media, and may even be unable to lose their property of producing colouring matters under natural or artificial conditions.

Red Pus.—There is occasionally observed a red cinnabar-coloured pus. Ferchmin found that the causation of this red pus was to be ascribed to a special form of bacillus with evenly rounded ends, which could be cultivated best at a temperature of 36° to 37° C. in various nutritive media—agar-agar, gelatine, blood-serum, potatoes. The red colouring matter is easily soluble in alcohol, and is insoluble in water, ether, and chloroform. In man, the red colour of the pus has nothing to do with the reparative process in a wound. In rabbits especially the bacillus has pathogenic properties.

Other Pus Microbes.—Among the other pus microbes mention should be made of the *Micrococcus pyogenes tenuis*, the *Bacillus pyogenes fœtidus* Passet (Fig. 298), the *Proteus vulgaris*, the *Staphylococcus cereus*, *albus*, and *flavus*, and Friedländer's pneumococcus. The majority of these bacteria are of subordinate importance as regards man. Recently the *Bacillus pyogenes fœtidus* has been carefully studied by Burci. He proved that it possessed not

only pyogenic but even septic properties for rabbits and mice, and sometimes produces in man severe acute suppuration, which has also been observed in the case of Friedländer's pneumococcus. Neumann and Haegler maintain that the *Micrococcus pyogenes tenuis* is identical with the pneumococcus of Fränkel and Weichselbaum. Fränkel's pneumococcus (Fig. 299), the typhoid bacilli (Fig. 262, page 263), and the *Bacterium coli commune* all produce suppuration. Fränkel's pneumococcus, which has been found to be the cause of various forms of inflammation and suppuration —e. g., pneumonia, empyema, meningitis, peritonitis, etc.—possesses a large capsule, and is hence known as the capsule coccus. In other cases the suppurative processes that occur in the course of the acute infectious diseases are caused by mixed infection with the pus cocci.

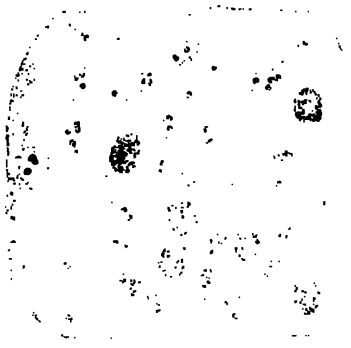


Fig. 299.—Diplococcus of Fränkel (capsule coccus). Pus taken from a case of empyema. × 1,000.

The micrococcus which causes suppurative inflammation of the urethra, the vagina, etc.—in other words, the gonococcus Neisser—is discussed in Regional Surgery.

Chronic abscesses, apart from those due to syphilis, glanders, and actinomycosis, are for the most part tubercular, and are caused by a characteristic bacillus (Koch).

Animals have been rendered immune against pus cocci, partly by inoculation of weakened cultures of the same, and partly by injection of the toxines isolated from the bacteria. The serum of such animals, particularly those made immune by the latter method, will render other animals unsusceptible to infection, and will cure the infection already present (see also antistreptococcus serum, page 330).

Different Forms of Inflammation and Suppuration as we meet them in Surgery.—Clinically, inflammation and suppuration may exist in various forms, either as an ordinary superficial suppuration limited to the wound, or the inflammation may extend to the parts in the neighbourhood of the injury and result in a cellulitis. This inflammation may lead to more or less circumscribed suppuration and abscess, or to diffuse and often rapidly spreading inflammatory and suppurative processes. The worst form of spreading inflammation and suppuration is the diffuse, foul-smelling inflammation of the cellular tissue, to which is given the name of septic phlegmon. Inflammation of the lymph vessels is called lymphangitis. Inflammations of the vessels, especially the veins (phlebitis), are very important, particularly as regards their dangerous sequelæ, due to the so-called emboli. The spreading inflammation which involves the skin and subcutaneous cellular tissue, the so-called erysipelas, is caused by an inflammation of the smaller lymph

channels, due to the *Streptococcus pyogenes*. The gangrenous breaking down of a granulating wound is called hospital gangrene, or wound diphtheria. Accompanying the inflammation and suppuration caused by micro-organisms, there is more or less fever, due to secondary infection or poisoning of the lymph and blood by the bacteria and the products of their metabolism. This may finally terminate in a fatal general systemic poisoning, which we shall learn about more particularly under the heading of Pyæmia and Septicæmia.

We shall first discuss acute inflammation of the lymph vessels (lymphangitis) and lymph glands (lymphadenitis).

§ 68. **Lymphangitis, Lymphadenitis.** *Acute Inflammation of the Lymph Vessels—Lymphangitis.*—Acute lymphangitis is characterised partly by a change in the lymph and walls of the lymph vessels, and partly by a perilymphangitis—i. e., an inflammation of the connective tissue surrounding the lymph vessels. The starting-point of a lymphangitis is usually some focus of infection; in other words, it is particularly apt to originate from an infected wound. The interruption of continuity in the skin is frequently most insignificant. The inflammatory irritant, the bacteria—and these are generally pus cocci—are taken up by the lymph vessels, and then they spread into the larger lymph channels, and wherever the bacteria become lodged they give rise to inflammation or thrombosis. Fischer found staphylococci to be the most frequent cause of lymphangitis (fifteen times in eighteen cases). In two cases streptococci were present alone, and in one case the *Bacterium coli commune*. As a result of the inflammation, the walls of the lymph vessels undergo a change, the endothelium may perish, and the entire wall may necrose, suppurate, etc. The lymphangitis may terminate in either a *restitutio ad integrum*, with absorption of the exudate and regeneration of the destroyed endothelium, or in abscess formation and necrosis of the walls of the lymph vessels and surrounding parts. Chronic inflammation of the lymph vessels leads to hyperplasia of the connective tissue, with induration of the lymph vessels and the tissue surrounding them.

Histological and Experimental Investigations upon the Movement of the Lymph during Inflammation.—The lymphatic system plays both a passive and an active part in inflammation. As long as the lymphatic vessels remain free from the inflammatory process they carry off the products of the inflammation, the emigrated leucocytes, and red blood-corpuscles, and the inflammatory process may resolve without going on to the formation of an abscess. An abscess is particularly apt to develop when the walls of the blood- and lymph-vessels become affected to a marked degree by the inflammatory agent, causing a retardation of the lymph current and insufficient removal of the inflammatory products. The slowing of the lymph current

may eventually become a complete stasis, with emigration of the leucocytes from the lymph channels and a corresponding infiltration of the tissues, resulting in abscess or gangrene of the affected parts. The changes which occur in lymph-vessels during inflammation are the same as those that occur in the blood-vessels.

Clinical Course of Acute Lymphangitis and Lymphadenitis.—Acute lymphangitis presents the following clinical picture: After the reception of a wound which is not treated aseptically, possibly a superficial abrasion of the skin on the fingers, the patient complains of pain in his entire arm, particularly when it is moved. When the patient is carefully examined there will usually be found a painful swelling of the epitrochlear and axillary glands, and from the still visible wound, or from the site where it existed, there will be seen red stripes leading up to the axilla. There will ordinarily be fever at the same time. The subsequent course of the disease varies. There either occurs, when proper treatment is adopted (rest, elevated position, ice), a complete *restitutio ad integrum*, or there is a continuation of the fever, with an increase of the local inflammatory symptoms leading to suppuration, generally in the form of a circumscribed abscess, e. g., in the lymphatic glands of the axilla and its neighbourhood. If the inflammation involves the more deeply lying lymph channels, there will be none of the above-mentioned red stripes in the skin. Acute inflammation may then suddenly appear in the corresponding lymphatic glands, which may either entirely resolve or go on to the formation of an abscess. Any lymphangitis is capable of giving rise to extensive inflammation and suppuration, to cellulitis, erysipelas, suppurative periostitis, generally accompanied by superficial necrosis of the neighbouring bone; also to general systemic infection, pyæmia, or septicæmia, terminating in death. All these possibilities depend upon the nature of the poison which is absorbed, or upon the virulence of the bacteria. Occasionally a severe phlegmon (§ 70) or a general systemic poisoning—particularly pyæmia—makes its appearance at a rather late period, long after the lymphangitis has entirely disappeared. In such cases the bacteria, which were first admitted through an interruption of the continuity of the skin, lie dormant in a lymph gland, and after the lapse of a certain length of time, either spontaneously or as the result of some cause which gives rise to inflammation (a blow, violent muscular movements, etc.), they may suddenly excite dangerous suppuration, and even cause death from pyæmia or general septic poisoning of the whole system. The study of the clinical course of lymphangitis, caused by bacterial infection, teaches us very plainly the necessity of treating with antiseptic principles even the most insignificant wound on the surface of the body.

The Treatment of Acute Lymphangitis and Lymphadenitis.—The treatment of acute lymphangitis and lymphadenitis in fresh cases consists in placing the affected portion of the body in a proper (elevated) position and giving it complete rest. For lymphangitis of the hand the arm should be fixed in the vertical position, upon Volkmann's suspension splint, for instance, which is very serviceable for this purpose (Fig. 202, page 209); the circulation is thus regulated, the afferent arterial current is checked, while the efferent current in the veins and lymphatics is made to flow off more readily, and the inflammatory swelling goes down, usually very rapidly. Ice should be applied in combination with the elevated position, or, if cold is not well borne, moist applications covered over with rubber tissue are excellent. In addition, grey mercurial ointment, very gently rubbed in, serves a useful purpose. The course of the disease must be carefully watched for the appearance of any localised redness and swelling indicating suppuration. Whenever suppuration can be demonstrated by fluctuation, the pus should be let out by incision at the earliest possible moment. Occasionally there will be noticed a great tendency to recurrence, especially after infection by cadaver poisoning (§ 76), and this recurring lymphangitis requires the most careful treatment. In such cases the warm baths recommended by Billroth and others are exceedingly useful. But search should always be carefully made for the possible presence of some focus of infection —some small wound, ulcer, pustule, etc.—and this, when found, should be treated upon antiseptic principles.

§ 69. **Arteritis and Phlebitis.** *Inflammation of the Walls of the Blood-vessels* (*Arteritis*, *Periarteritis*, *Phlebitis*, *Periphlebitis*).—We referred to inflammation of the walls of the vessels in the chapters on inflammation (§ 56) and the repair of wounds (§ 61). We saw that in every inflammation there occurred an alteration in the walls of the vessels, and that in every injury to a vessel and in the organisation of the thrombus an inflammation took place for the purpose of forming a cicatrix in the vessel. Every reparative process which takes place in a wound, even though aseptic in its nature, is an inflammatory change; but the aseptic repair of the injured vessels in a wound and the organisation of the thrombi into vascular connective tissue take place without any disturbance. When an injury, however, becomes infected by bacteria, the inflammation which then develops in the walls of the vessels becomes a matter of great importance.

We shall concern ourselves here principally with the inflammation of the walls of the vessels which results in suppuration—acute suppurative arteritis and phlebitis. Both of these inflammatory processes are very apt to be observed in conjunction with a suppurating wound or

ulcer, and are caused by micro-organisms, particularly those u which excite suppuration (staphylococcus, streptococcus, etc.).

The suppurative necrotic arteritis may be secondary to al isting disease of the surrounding tissues. In such cases the i tion first attacks the adventitia, and then extends to the inne the artery. If the artery contains a thrombus, as is the case s tion, the thrombus may, from the influence of the bacteria wl entered it, undergo a suppurative breaking down (thromb purulenta), and as a result of the sloughing of the arteri hæmorrhage may result which can endanger the life of the In other cases the suppurative thrombo-arteritis is developec boli, which carry the infectious material from some focus of into the blood-vessels, and, finding lodgment at some point there suppurative changes (metastatic abscesses).

In suppurative inflammation of the veins (phlebitis) pract same phenomena are observed. It is caused either by the trance of bacteria into the blood-vessels or by the extension to of an infectious inflam the surrounding parts; stance, an acute suppu flammation of the cellu may extend and involve of a vein. The inflam the wall of a vein, partic alteration which it pr the intima, the endotheli rise to the formation of bus and thrombo-phle else this order is reverse thrombus forms before t inflammation of the wal vein. In the veins thr

Fig. 300.—Thrombus in the valve of a vein (schematic).

Fig. 301.—Purulent thrombus of a vein (schematic).

particularly liable to develop in the region of the valves (I as the blood current flows more slowly at these points than a and the micro-organisms can thus more easily find lodgment (1 If in a suppurative thrombophlebitis the suppurating masses ing micrococci are swept off in the blood current to other pa body, wherever they are deposited they form the above-m metastatic abscesses resulting in pyæmia (§ 75). Buday main the lodgment of emboli made up of large particles of tissue of cocci is by no means necessary for the production of metast puration; the micro-organisms circulating in the blood ma

lodged in the endothelium of the vessels, and, growing very rapidly, break through their walls and give rise to phlebitis, thrombosis, and secondary phlegmonous processes. From what has just been said, it follows that every infection of the blood by micro-organisms, every suppurative inflammation, as soon as it extends to the walls of a vessel and reaches its lumen, is an exceedingly grave event on account of the spreading of the pus, or rather the bacteria, through the circulation.

Other inflammatory conditions, affecting the walls of the vessels, which concern the surgeon, are the acute inflammations which are particularly liable to occur in the intima of the aorta and the other arteries in pyæmic and septic infections of the general system, and which are due to the bacteria or the products of their metabolism circulating in the blood. Anatomically, these inflammations are characterised by the formation of groups of small cells in the intima and the other coats of the arteries, and by a fibrinous exudation into the intima, the latter being sometimes covered by a tough layer of fibrin.

It is important for the surgeon to bear in mind that the acute inflammations occurring in the walls of the vessels in conjunction with injuries to the soft parts are, after all, only partial manifestations of other local and general bacterial infections, such as a circumscribed or spreading cellulitis, erysipelas, pyæmia, or septicæmia. We shall therefore abstain from going into the diagnosis and treatment of inflammation of the walls of the vessels separately at present, as this subject will be brought up again in connection with the diagnosis and treatment of the inflammations or infections of the surrounding parts.

The phlebitis and the periphlebitis which sometimes occur in a more or less isolated form like a lymphangitis, and often originate from some insignificant injury, are diagnosed and treated briefly as follows: The subcutaneous veins feel like cords on account of the inflammatory thickening of their walls and the thrombosis which takes place in their interior. The process is essentially a periphlebitis with inflammatory infiltration of the sheaths of the vessels, and the veins are not always thrombosed. If, however, thrombi do exist in the veins, there is usually a corresponding œdematous swelling from the disturbance in the circulation. The treatment, particularly when the disease occurs in the lower extremity—and it sometimes occurs spontaneously in individuals with varicose dilatation of the veins—consists in placing the extremity in a properly elevated position, enveloping it in a moist dressing covered with rubber tissue, and, in addition, rubbing in mercurial ointment. This rubbing in or, more correctly, inunction of mercurial ointment for phlebitis must be done with the greatest caution and by

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gentle strokes of the hand, so as not to loosen any thrombi and have them carried off into the general circulation, as sudden death may result from cerebral embolism, or from the lodgment of an embolus in the pulmonary artery. By this treatment the local disease and the fever, when the latter exists, are caused to disappear; the cord-like veins becoming softer after the lapse of about six to eight days, and finally assuming, by degrees, a perfectly normal character. In such cases the phlebitis or the periphlebitis, whether there has been a thrombus formation or not, resolves to a complete *restitutio ad integrum*. If an abscess develops, the pus should be let out as soon as possible by an incision. A permanent occlusion of the vessel sometimes follows the organisation of a thrombus in a vein; this is particularly apt to happen in varicose veins of the leg. The so-called phleboliths (vein stones) result from calcification of venous thrombi. The manner in which thrombi develop, and the changes which occur in them, have been described on pages 296–298.

§ 70. **Cellulitis.**—By cellulitis is meant an inflammation of the soft parts which has a tendency to go on to suppuration, and is particularly liable to be located in the subcutaneous cellular tissue, or more deeply in the *intermuscular* cellular tissue, or beneath fascia, in the sheaths of tendons, in the periosteum, etc. We distinguish clinically two principal classes: the circumscribed and the diffuse. The former remains more or less limited to the neighbourhood of the original starting-point of the inflammation, while the latter has a marked tendency to spread and become a progressive process, the worst form of which is the very acute septic phlegmon; the inflammation sometimes manifests a tendency to spread with incredible rapidity.

It is not always plainly visible open wounds, or large recent injuries, which give rise to the cellulitis. Often enough it is an insignificant, perhaps already healed, abrasion of the epidermis near the nail, such as a scratch or a needle prick, which forms the starting-point for a spreading inflammation. Not infrequently, the cellulitis develops at some spot widely removed from the point of inoculation, from which the bacteria have been carried off in the lymph channels, finally lodging in some suitable locality, a lymph gland, for instance, where they grow and develop. The cellulitis which used to be called spontaneous in its origin does not exist. There is always an infection by bacteria, or by the products of their metabolism (*Staphylococcus pyogenes aureus*, *Streptococcus pyogenes*, the bacillus of malignant œdema, less often other pus cocci).

The Micro-organisms found in the Different Forms of Cellulitis; Pus Cocci.—Cellulitis is most frequently excited by the *Staphylococcus pyogenes au-*

reus and the *Streptococcus pyogenes*, though there are sometimes found other pus cocci, such as the *Staphylococcus pyogenes albus*, the *Micrococcus pyogenes tenuis*, the *Bacillus pyogenes fœtidus*, the *Bacillus pyocyaneus*, etc. (For a detailed description of these micro-organisms see pages 328 and 330). Occasionally there will be found only a relatively small number of cocci in the inflammatory collections, the tissues being caused to

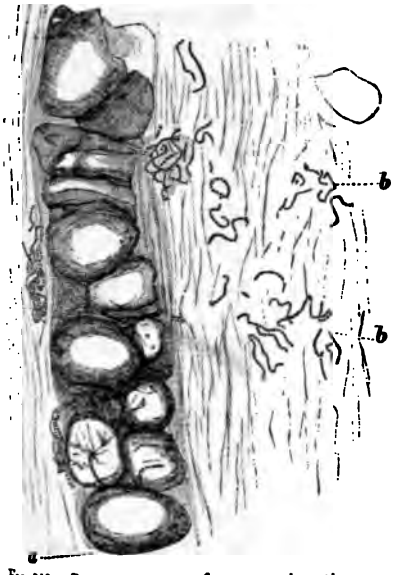


Fig. 302.—Streptococcus of progressive tissue necrosis in mice (Koch): *a*, cells of the cartilage in the ear; *b*, streptococci. × 700.

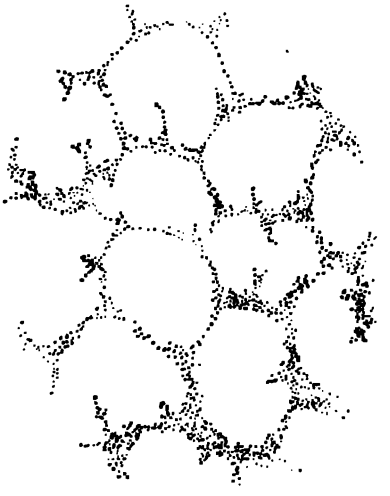


Fig. 303.—Intermuscular phlegmon of the forearm; *Streptococcus pyogenes* between the muscle bundles; stained with gentian violet (after Gram). × 250.

necrose extensively by the chemical products of the bacterial metabolism (Fig. 302). Again, in other cases, the cocci will be present in vast numbers (Fig. 303). The cellulitis excited by the streptococcus is characterised generally by a marked tendency to spread with great rapidity.

Bacillus of Malignant Œdema.—The worst forms of cellulitis, the so-called acute malignant œdema, progressive gangrenous emphysema (Pirogoff's acute purulent œdema, Maisonneuve's *gangrène foudroyante*), are caused by different anaërobic bacilli similar in appearance, of which Koch's *bacilli of malignant œdema* are the most constant. These little rods are probably identical with the *vibrions septiques* found by Pasteur in septicæmia. In man, malignant œdema occurs, for instance, in conjunction with a compound (open) fracture which does not receive aseptic treatment, or from any wound not aseptically treated. It is characterised by an extensive emphysema (evolution of gas) and by decomposition of the soft parts, and it almost always terminates in death after the lapse of a few days. The bacilli of malignant œdema are very apt to be found in the superficial strata of garden earth, in the dust collecting in the cracks of a floor, in all sorts of decomposing matter, in dirty water, etc. They are 3.0 to 3.5 μ long and about 1.0 μ broad; they have pointed or rounded ends, and often form long

filaments which may have different crooks or bends (Fig. 305). These bacilli are capable of very active movement, and possess cilia on the sides, which can be demonstrated by means of Löffler's method of staining. Spores make their appearance in the cultures by the end of the first day, forming best at a temperature of 37° C. (98.6° F.) (body temperature), in which they grow very rapidly, more slowly at ordinary room temperatures. At the time of spore-formation there is at first seen a slight granular appearance of the protoplasm, and then the formation of a central oval body (Fig. 304, *b*), which is not stainable. The spores are set free and develop into ciliated bacilli (Fig. 304) or threads of bacilli (Fig. 305). The œdema bacilli are strictly anaërobic, and can only be cultivated in an atmosphere free from oxygen. On gelatine plates the colonies form small shining knobs containing fluid, and the gelatine is liquefied. On agar plates they form a smokelike cloudiness with an ill-defined border. Puncture cultures in agar-agar, to which should be added one to two per cent. of grape sugar or sodium sulphate of indigo, develop in diffuse cloudy groups (Fig. 306). Cultures in blood serum show a homogeneous cloudiness in the line of the puncture. In the interior of the boiled potato the bacilli can be made to grow at a temperature of 38° C. (100.4° F.), and after several days the potato will be found riddled with a network of bacilli. Kitasato found that when the bacilli are cultivated in guinea-pig bouillon in the presence of hydrogen the fluid becomes cloudy, and then in two to three days clears again, showing the presence of a whitish precipitate. On opening the culture a foul, penetrating odour is given off. The bouillon culture remains virulent for months. The bacilli can be stained by all the aniline dyes, and will then frequently present a granular appearance. Gram's double stain cannot be used. If 0.1 to 0.3 cubic centimetres of a bouillon culture is injected into the subcutaneous tissue of mice and guinea-pigs, the animal thus inoculated will die in eight to fifteen hours. Upon post-mortem examination there will be found starting from the point of inoculation an extensive subcutaneous œdema, the fluid of which it consists being of a reddish colour and full of bacilli, with bubbles of gas scattered here and there. The bacilli will be found located principally in the serous cavities and in the fluids contained in the different organs. Guinea-pigs inoculated with the peritoneal fluid taken from such an animal will die very quickly. The bacilli can only be demonstrated in the blood several

Fig. 304.—Bacillus of malignant œdema: *a*, bacillus with flagella (× 1,000); *b*, spore formation.

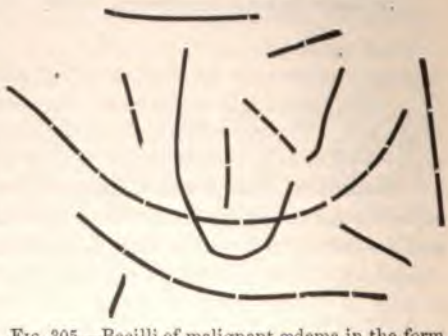


Fig. 305.—Bacilli of malignant œdema in the form of long threads.

days after death. If bouillon cultures are kept for ten minutes at a temperature of 115° C. (239° F.), or if they are filtered first through porcelain, and then about 100 cubic centimetres of the fluid rendered germ-free in either way are injected at three successive periods into the peritoneal cavity of a guinea-pig, the animal will be rendered immune from subsequent inoculations with the bacilli themselves. In other words, by injecting the products of the metabolism of the bacilli, the animals can be made unsusceptible to the bacilli.

Fig. 306.—Pure culture of the bacilli of malignant œdema. Agar-indigo-sodium sulphate.

Septic Emphysema and other Processes due to the Bacillus Coli Communis.—In a case of fatal septic emphysema in Gussenbauer's clinic, Chiari found that the *Bacillus coli communis* was the cause of the disease. Chiari attempted to excite a disease analogous to the "septic emphysema" in man with its gas formation, by injecting these bacilli into animals, but all his attempts failed. He could not bring about gas formation, though he made intravenous, intraperitoneal, and subcutaneous injections. The animals died from septicæmia, and the bacilli taken from their dead bodies and isolated in pure cultures evolved gas in considerable quantities. Bunge and others have confirmed this observation of Chiari's. The colon bacillus which is normally present in the mouth and gastro-intestinal canal produces extremely poisonous products of metabolism which are probably destroyed by the bile (Gilbert). It is of very variable virulence. Although usually harmless, it may, for unknown reasons, take on a high grade of virulence and give rise to various forms of inflammation, not only of the intestine (enteritis, dysentery, appendicitis) and its vicinity (peritonitis, liver abscess, endometritis) but also in distant organs (endocardium, meninges, thyroid gland, lungs, joints), and of the external coverings of the body. Other micro-organisms, such as streptococci, are sometimes present at the same time. According to Park the *Bacterium coli commune*, which occurs in different forms, is probably identical with Emmerich's *Bacillus neapolitanus*, the *Bacillus fœtidus*, the *Bacillus lactis aerogenes*, and a number of others.

Fränkel obtained from four cases of malignant œdema an anaërobic bacillus incapable of motion, which is similar to the anthrax bacillus, and sometimes occurs in the form of threads joined together. Subcutaneous injections of these cultures gave rise in guinea-pigs to typical malignant œdema.

Symptoms of a Circumscribed Cellulitis.—The symptoms of a more or less circumscribed cellulitis vary with the latter's situation; the more superficial the inflammation is, the plainer are the manifestations of the beginning cellulitis. In a superficial cellulitis, involving the skin and subcutaneous cellular tissue, the affected skin area is red and swollen, it feels hot, and is painful upon pressure. The skin is tense with œdema and cannot be lifted from the underlying parts. The in-

filtration feels hard at first, but subsequently, with the onset of suppuration, it becomes soft and doughy. Resolution of the inflammation without suppuration is a very rare occurrence. When the transition to pus has taken place, when an abscess is present, the affected area fluctuates—i. e., by alternating pressure made with both index fingers, the pus is caused to "fluctuate" or take on a wave motion, as any fluid will do when set in motion in a cavity with yielding walls. The pus either forces its way to the surface through the skin, which undergoes a gradual thinning process, or it is evacuated by an incision. The longer the suppuration is allowed to continue before being permitted to escape externally the more apt is the pus to burrow or extend to the parts in the neighbourhood of the abscess. In this way a spreading cellulitis dangerous to life may originate from a circumscribed cellulitis or suppuration.

If a circumscribed cellulitis is deeply situated at the outset, there is but little change in the skin, and neither swelling nor redness will be present, and only when the deep process draws near to the surface of the body will any of the above-described manifestations of its presence be revealed, the first being pain on pressure with œdema and redness of the skin.

In the neighbourhood of the circumscribed cellulitis there will be necrosis of the skin, and particularly of the fascia, tendons, tendon sheaths, muscles, and bones, in proportion to the amount of inflammatory infiltration and the ensuing suppurative breaking down. This death of tissue will be the more easily prevented or limited the earlier incisions are made, and the cavity washed out with antiseptic solutions of bichloride of mercury (1 to 1,000–2,000) or of carbolic acid (three per cent.). Every cellulitis which is not recognised early in its course may not only lead to extensive suppuration, with a proportionate destruction of tissue, but may even cause the death of the patient from a fatal general systemic infection—pyæmia, for instance—if the inflammatory elements are carried off and spread throughout the body by the blood-vessels. Under such conditions inflammation of the lymph channels (lymphangitis) and inflammation of the arteries and veins (arteritis, phlebitis) may be excited, with the formation of suppurating thrombi in the veins, also swellings and abscesses of the lymph glands, and metastatic abscesses in the internal organs, etc. Accompanying every circumscribed cellulitis there will be fever, the intensity of which will vary according to the virulence of the poison.

Felon or Paronychia.—A felon is, for the most part, at the outset a circumscribed inflammation of the subcutaneous cellular tissue of a finger, particularly about the nail and on the palmar aspect. Paronychia may appear

to begin spontaneously, but usually results from some injury, which may be only a very small abrasion of the epidermis. It is most apt to occur in individuals who are constantly receiving superficial injuries of the skin on their fingers, or in those who, like physicians and anatomists, frequently handle decomposing substances and thus infect themselves. The inflammation is more likely to spread into the deeper parts than to come to the surface; but there are also superficial forms of paronychia which spread very rapidly. The pain is usually very severe, as great pressure is exerted upon the nerves in the tense tissues. Death of tissue is a common occurrence as a result of the closure of the capillaries and small veins and arteries by pressure. If the paronychia extends to the tendon sheath, it usually spreads rapidly on account of the looseness of the tissue. From a neglected felon or paronychia, resulting in a spreading cellulitis, many a patient has suffered a serious loss of function of the hand, or the hand itself, or the forearm, or the whole arm, while the lives of some patients have not been saved even by an amputation.

Symptoms of the Diffuse Spreading Cellulitis.—The *diffuse spreading cellulitis*, formerly called diphtheritis of the cellular tissue, is usually very acute and much worse than the circumscribed variety. Like the latter, it is sometimes caused by very trifling injuries, such as a needle prick, or by a wound of the soft parts of a bone, or of a joint, which is not brought soon enough under the protection of antiseptic treatment. The local manifestations are at the outset the same as those of a circumscribed cellulitis. In many instances the disease begins with a severe chill and a proportionately high fever. The changes in the overlying skin may at first be very slight, and in fact it is not even reddened in the very dangerous deep forms of cellulitis which spread very rapidly. Just these cases are the ones so often unrecognised by the beginner. The process spreads quickly in the deep subfascial cellular tissue, and may terminate in a relatively short time in a fatal systemic infection. But in a spreading diffuse cellulitis the skin is generally involved, and has a dark or bluish-red colour, and not infrequently the epidermis is elevated by blebs; there is also an inflammatory infiltration of the skin which may make it as hard as a board. If the cellulitis is deeply situated, the skin feels more doughy and œdematous. The pain is very marked and usually there is a high fever. Not rarely the course of the disease is so acute that even after the expiration of four to five days disarticulation of the extremity may be necessary, or it may even then be too late to prevent the death of the patient from the general systemic poisoning. This form of septic, spreading cellulitis with high fever, extensive gangrenous destruction of tissue, and death by general systemic poisoning, has a very unfavourable prognosis, and has received the names of malignant œdema, progressive gangrenous emphysema, acute purulent œdema (Pirogoff), and *gangrène foudroyante*

(Maisonneuve). These dangerous forms of septic cellulitis are excited by the bacillus described on page 339.

If the diffuse inflammatory infiltrate in the subcutaneous cellular tissue, in the subfascial and intermuscular tissue, the sheaths of the tendons, and in the periosteum, is changed into pus and softens, the pain decreases, and there follows an extensive necrosis of the infiltrated tissues, including the skin, subcutaneous cellular tissue, fascia, muscles, tendons, and bone. Large sacs are formed filled with pus, the skin is lifted from the underlying parts, and joints are opened. As a result of the decomposition of the pus, emphysema, or the formation of gas, takes place, and this may be so marked that a peculiar crackling can be obtained on palpation, and a more or less tympanitic resonance will be elicited on percussion. If the diffuse cellulitis does not carry off the patient by general sepsis, the subsequent course of the disease is often very tedious, consisting in the gradual sloughing away of the gangrenous parts, and the proportionate formation of cicatricial contractures in the skin, tendons, muscles, joints, etc. The patient may also die in this stage from pyæmia, marasmus, parenchymatous degeneration of the internal organs, or from extension of the inflammation to vital parts—for example, from the skull to the meninges. Death may also result from hæmorrhage following suppurative perforation of the arteries or large veins, etc.

Prognosis of Cellulitis.—The *prognosis* of *cellulitis* varies greatly, depending upon the situation of the disease, the extent of the inflammation, and the kind of bacteria which excites the process. A cellulitis of the scalp, for instance, is a serious matter, from the danger of the inflammation spreading to the cranial cavity. In general, the superficial forms of cellulitis are not dangerous, while the deeper, subfascial, spreading forms, by causing general systemic infection, involve the greater risk to life the longer they remain unrecognised. The worst forms are those with progressive emphysema, caused by infection with the bacillus of malignant œdema; they often terminate fatally within a few days, before the local manifestations of the process become plainly marked. The prognosis of the others may be inferred from what has been said of them.

Treatment of Cellulitis.—The treatment of every cellulitis is practically the same, whether the inflammation is circumscribed or spreading. Much time used to be lost by the employment of poultices to obtain resolution of the inflammation. The knife should be used as soon as possible, and free incisions made to diminish the inflammatory tension of the tissues and to allow the pus to escape. We do not wait till suppuration and breaking down of the tissues have taken place but we immediately make an incision into the region where there is the most pain or the most pronounced swelling and inflammatory infiltra

tion, even though there may be as yet no pus present. If early incisions are thus made it may be possible to prevent death of tissue from taking place, particularly in the tendon sheaths, bones, etc., or at least to limit the amount of it, and cases treated in this manner will heal comparatively the most rapidly. The incisions should not be too small; it is better to make them too free rather than not large enough. The collection of pus should be laid bare throughout its whole extent by long incisions, and any pockets that may be present opened up. If the cellulitis is deep, the incision should be carried through the skin and fascia with the knife, and then the incision should be deepened with a blunt instrument—a closed dressing-forceps, for instance—down to the bone if necessary. In an extensive cellulitis the parts which appear sound must be examined very carefully, to determine whether pus may not have burrowed into or beneath them. After making the incisions the region in which there have been large collections of pus should be washed out vigorously with a 1 to 1,000 solution of bichloride of mercury, or three to five per cent. of carbolic acid. Schimmelbusch and others have, it is true, proved that the disinfection of infected wounds accomplishes very little or nothing, because the micro-organisms enter the interstices of the tissues very quickly and are thus out of reach of the action of the antiseptic solutions. Furthermore, it should be borne in mind that all bacteria after they have been killed have a pyogenic action through the poisonous protein substances that are set free, and upon these the antiseptic solutions have no action. If infected wound cavities, abscesses, etc., are freely opened and drained the pathogenic bacteria which are mostly obligate or facultative anaërobic are so hindered in their development by the entrance of air that they will usually die in part in consequence merely of the incision and drainage. Henle and Messner came to exactly opposite conclusions to those of Schimmelbusch, particularly if they used cultures of not too great virulence. According to them a general infection can be prevented by energetic disinfection of infected wounds. In any case we should make it the rule to disinfect infected wounds just as we have always done, and thus conform to the general practice. The discharge of pus is provided for by the use of drainage tubes or gauze packing. The best dressing for a circumscribed cellulitis is one which is antiseptic and absorbent—for example, iodoform gauze, sterilised mull and cotton, or pads of moss, jute, etc. Of course, the dressings should not exert any more than moderate pressure, to prevent pus from being forced into the connective-tissue spaces. In cellulitis of the fingers, I employ wet dressings of 1 per cent. acetate of aluminium and warm antiseptic baths, and then, later, iodoform and boric ointment. Poultices, which used to be so

much in vogue, should be condemned. Their use has caused much harm. To be able to determine whether there is any burrowing or retention of pus, the dressings must at first be frequently changed, possibly every day, or every second or third day; and not until the wound begins to granulate and suppuration ceases can the dressings be left undisturbed for a longer period. If the suppuration has been extensive, secondary sutures may be of service in hastening the repair after the packing has been removed.

In diffuse cellulitis, with extensive destruction of tissue, long incisions, followed by packing the wounds, are particularly valuable, and this may be subsequently supplemented with advantage by permanent irrigation (pages 181, 182). After the gangrenous tissues are cast off and the granulating stage has begun, a return may be made to antiseptic protective dressings of iodoform, dermatol, etc. To shorten the time required by a large granulating wound to become covered with skin, Thiersch's skin grafts are very useful (see § 42). In the treatment of every cellulitis, it is exceedingly important to secure for the inflamed part a proper position upon splints (§ 53), or in a sling (Fig. 181), etc. Elevation of an inflamed lower extremity, or vertical suspension of an inflamed hand, has an excellent effect, and sometimes works wonders. In the worst cases of septic cellulitis, amputation or disarticulation of the affected extremity will sometimes be found necessary in order to save the life of the patient. Unfortunately, the operation is sometimes performed too late, when general sepsis is already present.

The after-treatment of the sequelæ of cellulitis, the cicatricial contractures, necrosis of bone, etc., is conducted on the lines laid down for these conditions in another chapter (Contractures, Necrosis of Bones).

Phlegmasia Alba Dolens, or "milk leg," is an inflammation of the leg, rarely of both legs, running a slow course, with œdema and pain, principally due to venous thrombosis and occurring mostly in lying-in women and in cachectic patients (tuberculosis, carcinoma, etc.). The phlegmasia alba dolens of puerperal women is usually caused by the extension of an infectious inflammation of the pelvic connective tissue (parametritis), which ordinarily takes place in the second week after confinement. It terminates either in absorption of the inflammatory infiltrate, or in suppuration or gangrene, and rarely in death, which is then apt to be due to embolism or sepsis. The phlegmasia alba dolens of cachexia is mainly the result of venous stasis, caused by defective cardiac and pulmonary activity. It rarely goes on to suppuration.

§ 71. **Erysipelas.**—By erysipelas (from ἐρυθρός, red, and πέλλα, skin) is meant a spreading inflammation of the external cutaneous covering of the body, or rather of its smaller lymph channels, and of those of the subcutaneous cellular layer, caused by bacteria (streptococcus).

is a specific dermatitis, characterised (1) by a more or less rapid, for the most part, continuous extension along the surface, less often into the deeper parts; (2) by a toxic diseased state of the general system (intoxication fever) going hand in hand with the local inflammatory disease; and (3) generally by a complete *restitutio ad integrum* of the local inflammation, at least in the typical and uncomplicated cases. Gangrenous destructive processes, abscess formation, etc., take place in exceptional cases, and are then complications of the local disease.

Etiology of Erysipelas—Streptococcus of Erysipelas.—The micro-organism of erysipelas is generally a streptococcus (Figs. 295, 296, and 307) which was first obtained in pure cultures by Fehleisen. If man or animals are inoculated with this streptococcus true erysipelas will result. I have produced in animals (rabbits) true erysipelas by inoculating them with the contents of erysipelas blebs. The *Streptococcus erysipelatis* is found almost everywhere, particularly in the air of surgical wards (Eiselsberg).

Tissues affected by this disease, when examined by the microscope, reveal the erysipelas coccus, especially in the lymph spaces of the skin and subcutaneous cellular tissue, but it is usually not to be found in the blood-vessels. Not infrequently there will be large groups of the streptococcus present. Recent investigations have demonstrated that Fehleisen's erysipelas coccus is identical with the *Streptococcus pyogenes* described on page 329, and neither coccus can be distinguished from the other in any way. The description of the erysipelas coccus is given on page 329 (*Streptococcus pyogenes*). Suppuration and abscess occur in erysipelas, in all probability, when the streptococci develop in large numbers in the tissues outside of the lymph channels, or when there is a mixed infection—in other words, when the *Staphylococcus pyogenes aureus* or other pus cocci are present in addition to the *Streptococcus pyogenes*. The erysipelas which is complicated by gangrenous destructive processes is also probably caused by a mixed infection. Some authorities claim that erysipelas can be caused by staphylococci and typhoid bacilli. These are sometimes, without doubt, mixed infections. The combination of the streptococcus and typhoid bacillus is said to be particularly dangerous. Erysipelas may accordingly be said to be a non-specific disease. It is possible to differentiate two main varieties of the disease: 1, the true primary erysipelas caused almost exclusively by the streptococcus; and, 2, the less common secondary erysipelas that occurs in the course of infectious diseases, and is caused by the micro-organism that has given rise to the disease in question. Kaltenbach and others have made the interesting observation that erysipelas or the erysipelas coccus can be transmitted from the

Fig. 307.—Erysipelas cocci in two lymph vessels of the skin. × 700.

mother to the fœtus *in utero.* Bostroem has also demonstrated the fact that erysipelas cocci may enter the blood. He saw an acute catarrhal pneumonia develop in conjunction with a facial erysipelas, and after death the lymphatic vessels in the lungs were found filled with streptococci. The systemic intoxication, the fever in erysipelas, is, in the main, the result of the entrance into the circulation of the metabolic products of the streptococci. The streptococci themselves cannot, as a rule, be demonstrated in the blood.

Erysipelas of Mucous Membranes.—Erysipelatous inflammations occur not only in the external cutaneous coverings of the body but also in mucous membranes, especially the adjoining mucous membranes of the nose, mouth, and their adnexa, the trachea, the female genital tract, the bladder and the rectum. A cutaneous erysipelas may have involved these mucous membranes in its course, or, on the other hand, an erysipelatous inflammation may originate in the mucous membranes and extend from them to the skin in the form of a true erysipelas.

Erysipelas is a true infectious disease of wounds—i. e., it originates from some interruption of continuity which may be of the most insignificant character. Erysipelas does not originate spontaneously in the sense that used to be understood by the term. But there are forms of erysipelas—for instance, in systemic pyæmic poisoning—which have a metastatic origin. From any cellulitis a capillary lymphangitis, in other words, an erysipelas, may begin if the streptococci find lodgment and undergo subsequent development in the lymphatics of the skin and subcutaneous cellular tissue.

Location of Erysipelas.—As regards the localities affected by erysipelas, it occurs most frequently upon the face, often starting from some superficial abrasion of the skin, an ulcer in the nose, etc. Sometimes erysipelas cases occur in such numbers in some particular locality or in some hospital that the disease becomes epidemic, or, rather, endemic. Like every infectious-wound disease, erysipelas has become less common since the general use of antiseptic methods, and by strict asepsis it is possible to absolutely prevent an outbreak of erysipelas in a recent non-infected wound.

Symptomatology of Erysipelas.—The clinical picture of true, uncomplicated, cutaneous erysipelas is in the majority of instances characterised by the sudden occurrence of a rapidly rising, generally severe febrile movement which goes hand in hand with the erysipelatous inflammation of the skin. Subsequently there is just as rapid a defervescence, the temperature falling to the normal or below it when the local erysipelatous inflammation approaches its termination.

At the beginning of a true cutaneous erysipelas there will be noted the gradual appearance of a diffuse, somewhat elevated reddening of

the skin in immediate proximity to some small or large, recent or old, granulating or ulcerated wound of the skin. Frequently no wound of the skin can be made out at all; a slight cutaneous abrasion may have already healed. In other cases the point at which the streptococci of erysipelas have entered may be found in some adjoining mucous membrane or in some widely removed region. The redness is at the outset apt to be in spots, which often appear as though the lymphatic network had been injected with some red material. It was mentioned before that the streptococci of erysipelas spread mainly in the lymph channels of the skin and subcutaneous cellular tissue. The original spots very soon coalesce, forming an even, diffuse redness. Sometimes the reddening of the skin may start, as has been said, at a greater or less distance from a wound or interruption of continuity in the epidermis, and under such conditions the red stripes of a lymphangitis will connect the wound, on the fingers or toes, for instance, with the commencing red spot on the arm or on the leg or thigh (see Lymphangitis, § 68). The erysipelatous redness and swelling extend steadily now in this and now in that direction; they migrate, and may involve large areas of skin, or even the entire body, depending upon the intensity of the disease. The areas of skin first affected begin to turn pale again after the lapse of about two to four days, and sometimes earlier. In the regions where the skin is firmly attached to the underlying parts, to the bones or fascia, the erysipelas is apt to come to a standstill. Erysipelas generally extends progressively, though in cases of rapid, wandering erysipelas the disease may sometimes skip over an area of skin—for instance, in erysipelas of the foot—a large erysipelatous patch may suddenly appear in the region of the knee or thigh, and then soon afterwards coalesce with the patch on the foot. Under these conditions the two foci of erysipelas are usually connected by red stripes (lymphangitis). Occasionally, especially when occurring as a complication of pyæmia, there will be observed the so-called erratic, or, better, multiple erysipelas, which makes its appearance by metastasis upon different parts of the body.

The erysipelatous reddening of the skin ordinarily exhibits different tinges, varying from a bright to a dark red colour. In weak individuals, or when complicating pulmonary or cardiac affections (disturbances of circulation), or just before death or as the first stage of local death of tissue, the erysipelas has more of a bluish colour.

If there are gastric complications, or if occurring in drunkards, the cutaneous redness occasionally assumes a yellowish shade.

The swelling in an area affected by erysipelas is usually uniform, and the pain in the majority of cases is slight, but is increased on

pressure with the finger. Wherever the skin is superimposed upo distensible loose tissue there will be a marked erysipelatous exudation as in the scrotum, penis, the female genitals, the eyelids, or the lips. As a result of the saturation of the superficial layers of the cutis with serum during the course of an erysipelas there will often develop smaller or larger blebs, at the outset containing a clear serous fluid, and later, for the most part, pus. The blebs, as a usual thing, very soon dry up and form crusts.

The extension of the erysipelas takes place now from this and now from that border; it strides forward like a fire; it wanders, and hence the name erysipelas migrans or ambulans. For several days the erysipelas may spread in some particular direction, and then the process

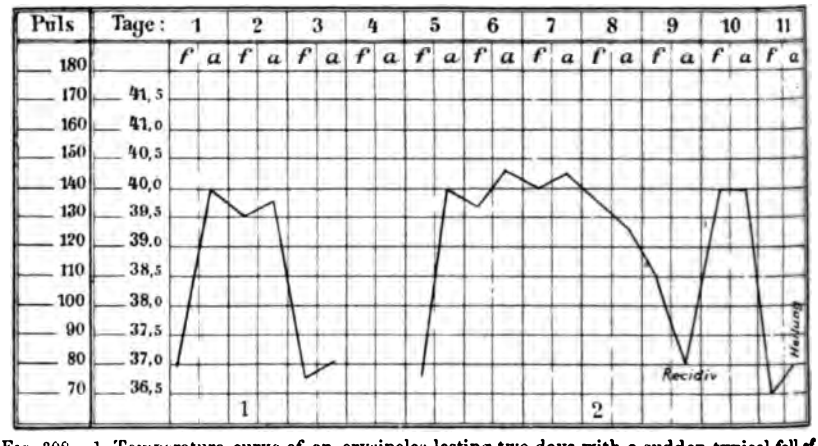


FIG. 308.—1. Temperature curve of an erysipelas lasting two days with a sudden typical fall of temperature; 2, temperature curve of an erysipelas with temporary fall of the temperature followed by a relapse of the erysipelas; recovery.

ceases and begins to spread from another border. It acts like a fire which cannot be controlled and which continues to burn wherever there is food for it, and the flame may suddenly again break out in a region where it seemed quenched. Pfleger thinks that the spread of erysipelas in a particular direction depends upon the course of the linear furrows of the skin. The rapidity with which the erysipelatous inflammation extends varies greatly, moving forward sometimes one to two centimetres within twenty-four hours, again four to eight or fifteen to twenty centimetres and more. Eventually, in the great majority of cases, the inflammatory redness and swelling terminate in a complete *restitutio ad integrum*; but suppuration may occasionally take place and multiple abscesses may form, or as a result of very pronounced swelling or from the extension of the disease to the deeper parts th

erysipelas may become complicated by phlegmonous changes, with extensive or limited death of tissue (erysipelas phlegmonosum, erysipelas gangrenosum). A process the reverse of this sometimes takes place—i.e., a deep-spreading cellulitis may come to the surface and run its course as an erysipelas of the skin. It has already been stated that in the complicated cases of erysipelas there is usually a mixed infection, due to the streptococcus and other bacteria.

The *general constitutional symptoms* correspond to the intensity and extent of the local process. The rise of temperature begins, as a rule, suddenly and rather violently, with one or more chills, and subsequently, when the erysipelas ceases, the temperature returns to the normal with equal rapidity. At the height of the disease the temperature generally rises to about 40° C. (104° F.) or more, and in exceptional cases it may reach 42° C. (107.6° F.). The fever may have either a continuous, a remittent, or an intermittent type (see pages 307, 309). Very often there will be pronounced gastric symptoms; the regions over the liver and stomach are tender on pressure, there is total loss of appetite, with nausea or vomiting, the thirst is ordinarily excessive, the tongue is heavily coated, dry, etc. The spleen is frequently much swollen; sometimes there is pain in the region of the kidneys, the urine is generally dark coloured, and may contain albumen, blood, bile pigment, and micrococci, and its quantity is diminished. If the erysipelas has a fatal termination, death is either the result of the general systemic poisoning by the products of the metabolism of the bacteria, or it is caused by some local complication, such as the extension of the erysipelas to some vital organ, to the cranial cavity, for example. Occasionally, if the erysipelas is protracted for a great length of time, the gradually increasing exhaustion of the patient may be the direct cause of death, which may take place suddenly after convalescence has begun.

There is no typical duration for an erysipelas, and recurrences are very common. The erysipelas may appear to have come to an end and then it will suddenly start up again. Its duration varies between hours and weeks. There are well-marked cases of erysipelas lasting twenty-four hours, and even a less time, and others which continue for a week, with now greater and now less intensity, and which may eventually involve the entire body, and possibly attack the same locality several times. The average duration of erysipelas amounts to about six to eight to ten days, but, as Billroth says, it is, as a general thing, unusual for the disease to continue more than fourteen days.

Habitual Erysipelas.—Many individuals are subject to what is called habitual erysipelas, a form of the disease recurring more or less period-

ically upon some particular portion of the body, most commonly the face, and resulting very often from a chronic nasal catarrh which is accompanied by ulceration. These recurrent attacks of erysipelas give rise not infrequently to chronic thickening of the skin (pachydermia) of the affected parts—e. g., on the lower extremity, the scrotum, vulva, face, etc.

Complications of Erysipelas.—As complications of erysipelas, there may be marked disturbances of the central nervous system due to the high fever or general systemic poisoning, particularly in an erysipelas of the head, which gives rise to meningitis. When the latter condition arises, there will be at the outset very marked symptoms of irritation, headache, vomiting, delirium, stupor, and finally convulsions. Exceptionally, even when convalescence has begun, and after the erysipelas and the fever have almost completely vanished, there will be observed in excitable persons a state of collapse with delirium of a more or less maniacal nature, accompanied by illusions and hallucinations of sight and hearing, the so-called collapse delirium. This temporary aberration of mind lasts usually only a few days. More rarely there are paralyses of the peripheral nerves as a result of central disturbance, or from peripheral neuritis caused by the erysipelatous inflammation. Leyden and Renvers observed an ataxia of the lower extremities which lasted a considerable time and followed the extension of an erysipelas of the head on to the back.

The most important of the local complications which may arise are suppuration and gangrene, and the combination with an inflammation of a phlegmonous character. The number of multiple abscesses which may make their appearance in the stage of convalescence is comparatively large —twenty to thirty or more. Landouzy saw as a result of an erysipelas involving the face, hairy portion of the scalp, the neck and back, sixty-nine abscesses, and some of them in areas which had not been affected by the erysipelas. Occasionally the suppurative process is more diffuse in its nature, and extends inwards, leading to suppuration of the muscles, tendon sheaths, joints, etc. (erysipelas phlegmonosum). The erysipelatous joint suppurations appear either at the outset and run a very acute course, or they first make their appearance during convalescence. Mention should also be made of phlebitis, lymphadenitis, and abscesses of the lymph glands. The lymph glands are usually swollen at an early stage of the disease. Gangrenous processes occurring in a true erysipelas are rare and generally of limited extent, and only extensive and severe when the erysipelas is complicated by changes of a phlegmonous character (*E. gangrenosum*). Among the other local complications which may arise, those affecting the eye should be included, such as impaired vision, rarely temporary blindness, panophthalmia with atrophy or suppuration of the eyeball, particularly when a facial erysipelas spreads to the cellular tissue of the orbit, iritis, ulcerative processes of the cornea, retinitis, and optic neuritis with atrophy of the optic nerves. There may also be catarrhal and suppurative processes affecting the ear, inflammation and suppuration of the parotid gland, dysphagia, and sometimes changes in the pharynx simulating diphtheria. Occasionally an inflammation of the lungs is produced (erysipelatous pneumonia

Pleurisy and cardiac affections (pericarditis, endocarditis, and myocarditis) are not common. Among the gastro-intestinal complications which may arise are ulcerations of the small intestine, and transitory hyperæmia of the intestinal mucous membrane accompanied by bloody diarrhœa. A similar condition may occur in patients who have received burns, and I have seen it in conjunction with extensive carbolic erythema (see page 158). The liver and spleen only exceptionally give rise to complications. Jaundice due to gastritis may occasionally be present, but hæmatogenous jaundice can also occur in severe cases of erysipelas as a result of the poisoning of the blood by the products of the bacterial metabolism, and this is usually a precursor of speedy death. Nephritis is often present as a complication, but it is generally of a temporary nature; only in very exceptional cases is the acute erysipelatous nephritis so marked as to cause uræmia. The latter is particularly dangerous when occurring in individuals already affected by kidney disease before they were attacked by erysipelas. Erysipelas is sometimes complicated by pyæmia and septicæmia (see §§ 74 and 75), and occasionally, as has been stated, erysipelas will occur in the course of a pyæmia.

Behaviour of the Wound in Erysipelas.—The interruption of continuity from which the erysipelas has sprung seldom manifests any complications. The healing of the wound *per primam intentionem* is not often disturbed; but the healing may sometimes be only apparent, and the wound may only unite superficially, while in its deeper parts there will be a retention of the secretion or of pus. A granulating wound will often exhibit a dry or dirty appearance, and may be covered by a peculiar croupous diphtheritic membrane. Erysipelas has occasionally been complicated by hospital gangrene (§ 72), especially before antisepsis was introduced.

The Curative Effect of Erysipelas.—Great interest attaches to the influence exerted by an intercurrent erysipelas of the skin upon new growths, particularly those of a lupoid or syphilitic nature, with or without ulceration, and also upon tumours, such as sarcoma and carcinoma. It has been noticed that the above-mentioned formations may permanently disappear, and that ulcers of long standing and chronic skin diseases, which resisted every kind of treatment, have improved and were healed after an erysipelas had passed over them. The French have given the appropriate name of *erysipèle salutaire* to an erysipelas which acts in this way, and numerous observations are recorded in literature upon the healing powers of erysipelas for all sorts of diseases. W. Busch, in particular, has recorded some very remarkable facts relating to the curative effect of erysipelas upon large tumours (sarcomata, lymphosarcomata), and he showed that the tumours underwent a rapid and extensive fatty metamorphosis, and could thus be absorbed and completely disappear. The curative power of erysipelas over tumours has been repeatedly made use of artificially for the purpose of destroying inoperable new growths. If inoculation of erysipelas is to be practised on any patient, it must be

borne in mind that the course of this disease cannot always be hel under control, and that there is a possibility of a fatal termination, a many cases testify. And although it is certainly justifiable to produc erysipelas artificially for the purpose of curing an inoperable tumour the patient should always be informed beforehand of the danger o the treatment. P. Bruns has recently made a critical investigation of the curative effects of erysipelas upon tumours, and succeeded in collecting twenty-two cases from literature. There was a complete and permanent cure in three cases of sarcoma, in two cicatricial keloids, and in a few lymphomata. In Bruns's own case a perfect recovery was brought about from a recurrent melano-sarcoma of the breast. In one case, observed by Janicke and Wisser, in which erysipelas inoculation was practised for an inoperable carcinoma of the breast, it could be demonstrated with the microscope that the erysipelas cocci actually destroyed the cancer cells. Consequently it is possible for erysipelas to cure a carcinoma.

Ferret observed the complete absorption within six days of the callus surrounding an already united fracture of the thigh, so that the fragments again became as freely movable as at the time of fracture. There is one other curious fact ascertained by Emmerich, Pawlowsky, and Di Mattei which should be mentioned in this connection. If rabbits and guinea-pigs are inoculated with erysipelas, during the ensuing three to ten days they will be unsusceptible to (immune from) anthrax; but after the lapse of this period the system is so weakened by its conflict with the erysipelas cocci that when the animal is infected by anthrax for the second time it succumbs more easily and rapidly than it normally would; in other words, after the lapse of this period the animal is no longer immune from anthrax. Quite recently a germ-free serum has been prepared from the blood of sheep infected with erysipelas cocci and used as a curative remedy for anthrax, malignant tumours, tuberculosis, glanders, and syphilis. It is impossible at present to give an accurate opinion regarding the value of this serum, but the reports that have been thus far made are not very encouraging.

Erysipelatous Inflammations of the Mucous Membranes.—Inflamma tions analogous to cutaneous erysipelas occur, as has been stated, in the mucous membranes which adjoin the skin, and consequently in th oral cavity and its adnexa (nose, pharynx, larynx), the female genit tract, the bladder, and the rectum. Erysipelatous wandering pneu monia is described in books on internal medicine.

Diagnosis of Erysipelas.—The *diagnosis* of the ordinary cutaneous er *sipelas* is very simple in typical cases, and can hardly cause any troub The gradually spreading local redness and swelling of the skin and t

accompanying fever are so characteristic that there can scarcely be any confusion, even with the exanthemata. Erythema bears the closest resemblance to erysipelas, but in erythema there is usually no fever, and the swelling and pain are not nearly so pronounced as in erysipelas.

Prognosis.—In general, the *prognosis* of erysipelas is not unfavourable, but in no case of this disease, no matter how mild it may seem, can we be certain of a satisfactory termination. There are many circumstances which affect the prognosis of an erysipelas, particularly its location, the constitution and age of the patient, the complications which may arise, the intensity and duration of the local disease, and of the fever, etc. The more extensive the inflammation the higher the fever, and the longer it lasts so much the worse is the prognosis. The mortality given by various authors differs very much, the average being about eleven per cent.

Treatment of Erysipelas.—A great number of remedies have been employed for erysipelas, and the fact that the treatment varies so much shows that nothing is entirely satisfactory; and it is my opinion that, as yet, we have no very reliable and effective method of treatment. Since the disease has no typical duration, it is very natural that mistakes should be made in regard to the curative power of this or that remedy.

The best way of preventing erysipelas consists in treating every interruption of continuity, whether recent or old, large or small, upon antiseptic or aseptic principles; and whenever a dressing is changed it should be done with a careful observance of the rules of antisepsis. Erysipelas is never seen to start from a wound that has been made in the course of a strictly aseptic operation. When the erysipelas has broken out, the treatment should be directed against the general febrile disturbance and the local disease. The treatment of the fever has been discussed in § 62.

The treatment of the local disease consists in placing the affected portion of the body in a suitable position. Ice is employed chiefly in erysipelas of the head. Numerous remedies are used to combat the erysipelatous inflammation. At the outset of the disease parenchymatous injections of 2 to 3 per cent. carbolic acid at the margin of the inflammation are to be recommended. The contents of three to five hypodermic syringes are injected along the advancing edge of the inflamed and through the sound skin, and these injections are repeated once or twice, depending upon the acuteness or rapidity of spread of the inflammation. In the same way subcutaneous injections of bichloride, salicylic acid, cocaine, ergotin (5 to 8 centigrammes in alcohol and glycerine equal parts) have been employed.

Estlander recommends subcutaneous injections of morphine, particularly when combined with a daily painting of the diseased area with tincture of iodine. Lücke and others have used inunctions of

turpentine with success; it is rubbed into the diseased area of skin two to three to five times a day with a brush or piece of cotton. Strong tincture of iodine can be applied with a brush seven to eight times a day; nitrate of silver (one to four, or eight, or ten) is highly praised; also the application of compresses wet in a three- to five-per-cent. solution of carbolic acid, or in a five- to ten-per-cent. solution of trichlorphenol; fifty to eighty per cent. resorcin ointment may be spread over the affected part, etc. Another method is to rub the inflamed area vigorously with absolute alcohol and then apply cotton saturated with the same. This is done every half hour during the first twenty-four hours, and later every three to four hours. Heppel recommends painting the borders of the erysipelatous area with a ten-per-cent. alcoholic solution of carbolic acid, covering a portion of skin about two inches wide all around the diseased spot. The following methods have also been recommended for treating the disease locally: Covering the erysipelatous area of skin with ammonium sulpho-ichthyolicum mixed with equal parts of lard, or with ichthyol and vaseline (equal parts), and placing over this absorbent cotton; covering the erysipelatous area close up to the surrounding healthy skin with an ointment of one part creolin, four of iodoform, and ten of lanoline (Koch and Mracek), or with white lead, or with a varnish of linseed oil, over which some water-tight material is applied, etc. Kühnast, from his experiments in Kraske's clinic, recommends multiple scarifications and incisions, followed by irrigation with a five-per-cent. solution of carbolic acid; also the application to the erysipelatous area of compresses wet with a two-and-a-half-per-cent. solution of carbolic acid, the compresses to be changed once or twice a day. Riedel and Classen recommend scarification, particularly at the advancing margins of the erysipelas. Scarifications are exceedingly effective, especially when made chiefly or exclusively in the healthy adjoining skin. Madelung, W. Meyer, and others have obtained satisfactory results from scarification and application of compresses wet in a three- to five-per-cent. solution of carbolic acid or in a 1 to 1,000–3,000 solution of bichloride of mercury. This latter method of treatment is coming more and more into favour at present. Larrey preferred to make linear or punctate cauterisations with the red-hot iron, aiming at retaining the erysipelas within the barriers made by the eschars. Wölfler has prevented the spread of an erysipelas by means of the mechanical compression produced by placing strips of adhesive plaster along its borders. For the same purpose Niehans employed collodion, applying the latter around an extremity over a space about two handbreadths in width, thus encircling the extremity with the collodion as with a bandage. Kroell recom-

mends strips of caoutchouc for the same purpose. Winiwarter and Fraipont speak well of the following method of treatment: The part affected by the erysipelas and the wound are soaked for ten minutes in a bath of 1 to 3,000 bichloride, or the latter is used in the form of an irrigation for a longer period of time; the erysipelatous area is then dried, and it and the adjoining healthy skin are covered with tar, over which is applied a dressing wet with Burow's solution (see page 162); then iodoform gauze which has been dipped in a bichloride solution is placed on the wound, and the whole dressing is bandaged lightly in position.

It has been attempted to combat the erysipelatous inflammation by the internal administration of drugs. English surgeons, in particular, give iron internally (liq. ferri chlorat., in large doses, fifteen to twenty drops every hour, or even 2.0 grammes or more); others use liq. ferri sesquichlorati., ten to fifteen drops every two to three hours; ergotine, iodide of potassium, and belladonna have been used for the same purpose. Haberkorn has recently employed with success benzoate of sodium in mucilaginous solutions, or in some effervescing water, in doses of fifteen to twenty grammes a day; no local treatment is made use of. The effectiveness of all internal medication is exceedingly doubtful. Camphor (internally or in the form of subcutaneous injections) has but little value, though it was highly recommended by Pirogoff.

The treatment of the complications, particularly the abscesses, gangrenous processes, and the inflammations of joints, should be conducted on the principles laid down for these conditions. At the time of the outbreak of the erysipelas, or when the case is met with in a later stage, the wound from which the disease starts should be carefully examined and treated antiseptically, and if any blood or pus is held in retention it should be let out by removing a few sutures, by separating the agglutinated margins of the wound, by making incisions, etc.

If it is desired to inoculate an erysipelas for therapeutic purposes upon an inoperable tumour or diseases of the skin, it should always be borne in mind that infection by the streptococcus of erysipelas may cause the death of the patient.

Zoönotic Erysipelas—Wandering Erythema (*Erythema migrans*).—The so-called erysipeloid or wandering erythema occurs almost exclusively on the hands, and attacks most commonly individuals who handle all sorts of dead animal substances, dealers in game or fish, cooks, restaurant keepers, butchers, tanners, oyster openers, and those who come much in contact with cheese, herring, etc. Erysipeloid is a disease of wounds which is not very

infectious in character, and affects the hands almost exclusively, some i fectious substance being inoculated into small wounds. After inoculatio there ensues a moderate infiltration of the skin, giving the latter a dark-r discolouration; there is no fever, and the disease spreads very slowly, wit an itching, prickling sensation, and it may take eight days to extend, for in stance, from the finger tip to the metacarpus. The reddening of the skin more often occurs in spots; less frequently it is of a diffuse character. It is only very exceptionally that the erysipeloid extends as far as the wrist, and it never reaches the forearm. The disease is often very stubborn and persistent, lasting sometimes three to four to six weeks unless proper treatment is adopted; but in other cases it may disappear spontaneously in one to two to three weeks. Rosenbach found that a coccus-like body was the cause of the erysipeloid; it is larger than the staphylococcus, grows best in gelatine at a temperature of 20° C., forms twisted filaments of varying length, and bears a remarkable resemblance to a form of microbe described by Cohn under the name of cladothrix dichotoma. Rosenbach and Cordua have produced this erysipeloid by inoculations practised on themselves.

The best method of treating the zoönotic erysipeloid consists in cutaneous injections of a three-per-cent. solution of carbolic acid into the inflamed area of skin, and into the healthy skin immediately adjoining its outer borders.

§ 72. **Hospital Gangrene—Wound Diphtheria.**—Hospital gangrene (*Gangræna nosocomialis*), or wound diphtheria, used to be, in the pre-antiseptic era, a very common disease, particularly in hospitals with bad hygienic arrangements, and in military practice, but if antiseptic treatment is used it never occurs. Hospital gangrene is a local wound disease, always bacterial in its origin, and consists essentially of a gangrenous destruction of the granulations and adjoining tissues.

Etiology of Hospital Gangrene.—The micro-organism of hospital gangrene has not as yet been discovered. Rosenbach, in his last monograph on hospital gangrene, could give no information upon the exciting cause of the disease. The identity of hospital gangrene and diphtheria is still an open question, and many arguments *pro* and *con* have been advanced by different authors. W. Roser and Rosenbach have been the most outspoken against the identity of the two diseases. Brunner understands by wound diphtheria that kind of infection of wounds which is caused by the Löffler bacillus, the excitant of ordinary diphtheria. This sometimes occurs in the tracheotomy wound in diphtheritic stenosis of the larynx, and also occurs as an independent infection on different parts of the body without diphtheria of the fauces. Such wounds have an ulcerative character, and besides the Löffler bacillus there are usually pus coc present (staphylococcus and streptococcus). Wound diphtheria do not, however, correspond with true hospital gangrene in its seve forms. The latter are practically never observed since the period

antiseptic surgery, and hence it can be understood why the specific cause of true hospital gangrene is unknown to us. Hospital gangrene is probably a marked putrefaction of the wound caused by a number of micro-organisms. The pathological changes in hospital gangrene, like those in diphtheria of the pharynx, consist in an infarct of the infected wound, or in a coagulation necrosis, as it is called by Cohnheim and Weigert, in which are present great numbers of micrococci and bacteria of decomposition.

Clinical Cause of Hospital Gangrene.—Clinically the disease occurs in one of three forms: 1, The superficial croupous and diphtheritic; 2, the ulcerative diphtheritic, and, 3, the pulpy, the latter being the most malignant form. These different forms of the disease may run into each other, and clinically cannot always be sharply distinguished. The croupous or diphtheritic form of hospital gangrene is characterised by the development of hæmorrhagic foci accompanied by swelling, the foci subsequently breaking down and forming a foul, suppurating, jelly-like mass. By immediate treatment of the diphtheritic area with a concentrated chloride-of-zinc solution, or with the Paquelin thermo-cautery, the spread of this lowest grade of hospital gangrene can generally be arrested. The ulcerative form of the disease also begins with the development of hæmorrhagic spots having a grey or greyish-yellow colour, and at the outset is of limited extent; but in a relatively short space of time it spreads over the granulating surface and changes the latter into a grey or greyish-yellow mass, which subsequently breaks down into a gangrenous pulp. This gangrenous destruction of tissue may steadily advance inwards, and superficially may involve the skin adjoining the granulating surface by a spreading of the ulcerative process. The ulcerative form of hospital gangrene may change into the pulpy or most dangerous kind of wound diphtheria. In the pulpy form, according to König, there occurs, as a general rule, a rapid swelling of the tissues in consequence of the extensive hæmorrhages into the granulations, followed by putrefaction of the entire mass and the evolution of gases of decomposition. The borders of the wound are red and very painful. The swollen, grey, or greyish-red wound looks, as König says, like a soft, decomposing spleen or mass of brain tissue.

The *course* of hospital gangrene depends, in general, upon whether the gangrene of the wound remains superficial or extends into the more deeply lying parts. Every form of hospital gangrene may destroy the skin and spread into the subjacent tissues, particularly if it is of the pulpy variety. The gangrenous changes advance very rapidly, and within twenty-four hours cause the wound to become double its origi-

nal size, or even larger, but in other cases the changes take a much longer time.

The general symptoms correspond to the severity of the local disease. The fever may be continuous or remittent, with intercurrent chills. Very frequently the local disease begins with a rigour and a fever of 40° to 41° C. (104° to 105.8° F.).

Prognosis of Hospital Gangrene.—The prognosis of hospital gangrene depends upon the form of the gangrene and the nature of the treatment. The pulpy form of hospital gangrene has the most unfavourable prognosis of all. The strength of the patient and the conditions under which he has lived must be taken into account. The milder forms of hospital gangrene will often get well spontaneously, while the more severe forms will frequently cause death by general septic poisoning, unless the spread of the gangrenous process is combated sufficiently early and energetically by proper treatment. Recurrences of the disease take place not infrequently.

Treatment of Hospital Gangrene.—The treatment of hospital gangrene consists in the energetic use of the Paquelin thermo-cautery and of caustics, particularly nitric acid or chloride of zinc, to check the spread of the gangrene. Deeply placed gangrenous foci must be laid open with the knife, to permit the pus to escape and to enable the suppurating region to be energetically disinfected with a 1 to 1,000 solution of bichloride of mercury. Iodoform or naphthaline are excellent substances to apply in the dressings; or, if the gangrene is very extensive, antiseptic irrigation may be practised, as described on pages 181 and 182. If it becomes necessary to amputate a gangrenous limb, the operation should be performed with the strictest antiseptic precautions, after first energetically disinfecting the gangrenous focus, or burning it with the Paquelin thermo-cautery and covering it with an antiseptic dressing wet with bichloride.

Every patient with wound diphtheria should be isolated with the greatest possible care, as a protective measure for the other patients. Hospital gangrene, as has been said, does not occur at present with the antiseptic method of treating wounds; but in the time of war, where the rules of antisepsis cannot always be strictly observed, hospital gangrene is likely to make its appearance.

§ 73. **Traumatic Tetanus.**—Tetanus is an infectious-wound disease characterised by cramp-like contractions of the muscles of the lower jaw alone (trismus), or by contractions of certain other groups of muscles, or of the muscles of the whole body (tetanus). The tetanic contractions often begin in the muscles in the vicinity of the injury where the poison was inoculated, and later tetanic spasms of the other muscles follow.

Etiology of Tetanus.—The etiology of tetanus has been recently advanced by Nicolaier, Brieger, and particularly Kitasato. There used to be a great many theories concerning the nature and etiology of tetanus, but they did not account satisfactorily for its occurrence in the injured, and they are to be looked upon at present as untenable. The recent investigations of Nicolaier, Brieger, and Kitasato have proved beyond a doubt that tetanus is produced by a specific bacillus discovered by Nicolaier, and first obtained in pure cultures by Kitasato (Fig. 309).

The injuries which may be followed by tetanus are of every description. Sometimes they are severe, and involve both soft parts and bones, such as compound fractures, and sometimes less severe, such as burns, frost-bites, or insignificant wounds of the skin or a granulating surface, or perhaps only a small punctured wound, etc. Tetanus has been known to come from a blister and the sting of a bee. We can easily understand, from the analogous origin of other infectious-wound diseases, particularly anthrax, how tetanus may follow the very slightest interruption of continuity in the skin. The disease is particularly apt to occur as a result of injuries to the hands or feet, in which are lodged foreign bodies, such as bits of earth or splinters of wood. Animals, such as horses, may often be the means of transmitting the tetanus bacillus to man. Occasionally the disease appears to break out after the lapse of a certain period of incubation, and consequently it is possible for tetanus to occur after the wound has entirely healed. The disease may become endemic under certain conditions—for instance, in hospitals where the rules of antisepsis and asepsis are not strictly observed.

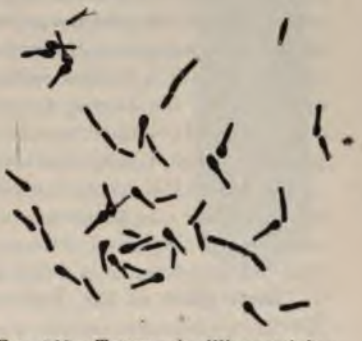


Fig. 309.—Tetanus bacilli containing spores, from an agar culture. × 1,000.

Experimental Inoculation of Tetanus.—Carle, Rattone, Rosenbach, and a number of others have inoculated animals—e. g., guinea-pigs—with tetanus from human subjects, and then inoculated other animals from the first ones. Nicolaier performed some very interesting experiments in Flügge's laboratory. While carefully studying the micro-organisms in surface soil, he was surprised to find that a disease similar to human tetanus was produced in a considerable number of cases (sixty-nine times in one hundred and forty experimental inoculations) by inoculating animals with earth taken from widely separated sources (Berlin, Wiesbaden, Leipsic, and Göttingen). The inoculations with the earth were practised at the root of the tail in white

and yellow mice, and beneath the skin in rabbits and guinea-pigs. In mice after the lapse of one and a half to two and a half days, or four to five days in rabbits, cramps occurred in the muscles in the neighbourhood of the region inoculated, and later the tetanus extended to the muscles of the other extremities and to those of the back and the nape of the neck. In rabbits, the muscles of the jaw became rigid in a state of tonic spasm, and death occurred after the lapse of one and a half to two days. Mice died twelve to twenty hours after the first symptoms of poisoning made their appearance. Dogs did not react at all when inoculated.

The post-mortem examination revealed, as in man, very little which was distinctive. Microscopically, in the slight amount of pus at the point of inoculation, micrococci were found, and particularly a peculiar bristle-shaped rod carrying spores. Nicolaier was not able to obtain pure cultures of this bacillus; he could not separate them from other bacilli, and consequently it was believed that tetanus was caused by a kind of symbiosis of different bacteria. When the earth was heated for an hour the inoculations were unsuccessful. Attempts at producing infection by pus taken from animals at the point where they were inoculated succeeded in sixty-four out of eighty-eight experiments, the disease running a more rapid course than when earth was employed. Inoculations with pieces of the infected tissues succeeded only fourteen times in fifty-two cases.

Socin has also excited true tetanus by making inoculations with garden earth. I saw one fatal case of tetanus following a compound fracture which had become befouled with earth. The patient came under my care after well-marked tetanus had developed.

Description of the Tetanus Bacillus.—Kitasato was the first to isolate Nicolaier's tetanus bacillus from the other bacteria found accompanying it; he cultivated it and excited tetanus in animals by inoculating them with the pure culture, and thus established the correctness of the suppositions which had existed about the disease. Kitasato placed in the necessary culture medium a small piece of tissue taken from the immediate neighbourhood of a suppurating wound in a man who had died of tetanus. The culture when placed in the incubator revealed a luxuriant growth of bacteria; but the kind which carried spores at one extremity developed the most rapidly, while the others only began to grow after the lapse of a certain length of time. Before these latter could develop Kitasato heated the mixed culture to a temperature of 80° C. and destroyed all the bacilli which had not taken on their permanent form, leaving only those which were capable of forming spores. From these he made a pure culture, which, when inoculated upon animals, established the fact that the bacillus containing spores in one of its extremities, and first discovered by Nicolaier, was actually the true bacillus of tetanus.

Pathogenesis of Tetanus.—The tetanus bacillus (Fig. 309) is often present in the surface layer of ordinary earth, in decaying masonry, decomposing fluids, manure, or splinters of wood found in wounds, and in the pus from wounds on persons who have died of tetanus. It is a slender rod with distinct motility, and forms spores in artificial cultures at a high temperature. These spores are found at one end of the bacillus, and give it the familiar drum stick shape. The bacilli collect usually in irregular groups, and sometimes

long filaments, upon which the divisions between the segments are distinguishable. The bacillus grows very slowly, best at a tem- f 36° to 38° C., while below 16° C. no development takes place. It is naërobic—i. e., it grows only when atmospheric air

In the presence of oxygen the bacillus quickly an atmosphere of pure hydrogen, small ray-like evelop slowly upon gelatine plates after the lapse ays; they liquefy the nutritive medium with the of gas, and present an appearance similar to the us (a rather thick, solid centre, with radiating fila- Stab cultures in a test tube containing a consider- nt of grape-sugar gelatine, or in gelatine to which added 0.1 per cent. of indigo-sulphate of sodium, lture at the bottom of the tube having the appear- rated in Fig. 310. At the end of the first week it ething like a fir-tree—i. e., numerous fine processes twards from the line of puncture, simulating the *figurans*. Subsequently the gelatine surrounding is liquefied, and there is an evolution of gas. In containing agar, to which has been added one to ent. of grape sugar or indigo-sulphate of sodium, h at the proper incubation temperature is more luxuriant, and after the first or second twenty- the culture causes an evolution of gas which has eristic unpleasant odour. In grape-sugar bouillon h of the culture is exceedingly vigorous, and is ac- l by the formation of a large amount of gas. In m, at a temperature of 34° to 38° C., after the lapse three days small round cavities develop, which coalesce.

FIG. 310. — Tetanus culture. Stab culture in gelatine with indigo - sulphate of sodium. Seven days old.

formation, at a temperature of 37° C., takes place in twenty hours, s at one end of the bacillus, this portion of the cell swelling, and the appearance of a drum-stick (Fig. 309). The spores have great nd will remain alive when exposed in a moist state to a tempera- ° C. for one hour, but are destroyed in five minutes when exposed t a temperature of 100° C. Dried pus containing spores retains its after the expiration of sixteen months. The tetanus bacillus is ained by the ordinary aniline dyes. Gram's method can also be

nall amount of a pure culture is inoculated upon mice, rats, guinea- bbits, the first kind will manifest the first symptoms of the disease in twenty-four hours, the last in two to three days. If horses, sheep, e inoculated with the pure culture they will develop typical tetanus. festations of the disease are at first local, and confined to the parts ely adjoining the point of infection, from which they gradually d the animal then dies in a short time. At the point of infection infiltration of the tissues and hyperæmia, but no suppuration, and it may be possible to demonstrate the presence of the bacilli; but never found in the different organs or in the blood. The most

typical picture of tetanus, usually with rapidly fatal outcome, is obtained by injecting subcutaneously the germ-free filtrate of bouillon cultures of the tetanus bacilli. The period of incubation is longer and death takes place later when material containing the bacillus is inoculated. Tetanus bacilli produce their harmful action not by multiplication of the bacilli within the body but by the formation of very poisonous products of metabolism. The toxines produced by the bacilli have an action similar to strychnine. Many authorities have attempted to isolate the tetanus toxine. Weyl, Kitasato, and Brieger obtained a highly poisonous substance closely allied to the albuminoid bodies (tetanotoxalbumen), which gives rise to tetanus in animals after a certain period of incubation, but in not so typical a form as after infection with the tetanus bacilli or injection of sterilised cultures.

According to Courmont and Doyon, the tetanus bacilli form at first a soluble non-poisonous ferment by which the real tetanus poison is produced at the expense of the organism. Several poisonous bodies are perhaps formed during the incubation period. Brieger obtained some time ago four toxines in a pure state, viz., tetanine $C_{12}H_{26}N_2O_4$, tetanotoxine $C_5H_{11}N$, spasmotoxine, and a toxine hydrochlorate. Very small amounts of these toxines produced in animals tetanic symptoms, but not typical tetanus.

The Tetanus Poison.—The tetanus poison is found in the serum of the blood, and after passing through the blood is excreted by the kidneys, causing the latter to become toxic. Bruschetini caused tetanus by subcutaneous injections of the urine of animals infected with tetanus. Buschke and Oergel found drops of fat almost constantly in the blood of the animals experimented with. The liver, spleen, and muscles also contain a very poisonous toxalbumen that kills small animals immediately. The toxines that are formed by the tetanus bacillus at the point of entrance are taken up partly by the lymph channels and remain for a certain length of time in the regionary lymph glands (Büdinger); others act directly from their place of formation upon the peripheral nerves, and are probably transmitted in the latter directly to the spinal cord. This explains the development of the local tetanus at the place of inoculation, and then later the general tetanus. The investigations of Brunner and others have given us more exact details of the mode of action of the tetanus poison upon the nervous system. It is claimed that the poison enters into chemical composition with the nerve substance of the central nervous system, or is neutralized by the protective materials formed here (antitoxines), so that finally it can no longer be demonstrated here in animals that have died of tetanus, while in the other organs large quantities of poison can be found. The tetanus poison acts like strychnine in causing increased excitability of the spinal cordi—i. e., the motor cells in the anterior horns—but in order to produce muscular spasms there must also be a sensory stimulus. The excitability of the sensory nerves has been found by some to be markedly increased, while that of the motor nerves remains unchanged. The slightest peripheral stimulus becomes augmented in the sensory tracts so that it causes a contracture. The action of the poison is accordingly partly a peripheral and partly a central one (Brunner). Somani fed herbivora and carnivora with pure cultures of tetanus bacilli and the meat from animals that had died of tetanus, and found that all the animals remained healthy. The fæces of the animals, particularly the herbivora

contained an active tetanus poison which, as already known, can be spread by the fæces and manure of horses, for example.

Tetanus Immunity in Animals.—Great interest attaches to the experiments of Behring and Kitasato relating to the production in animals of immunity from tetanus. These authors succeeded in curing infected animals, and in so treating healthy ones that they were never afterwards affected by the tetanus bacillus. The blood and serum of rabbits which have been rendered immune from tetanus possess the power of destroying the tetanus poison. They are both prophylactic and curative. By transfusion of blood or serum remarkable therapeutic effects can be obtained; that is, infected animals can be cured, and healthy ones—mice, for example—can be rendered permanently immune. The artificially acquired immunity is transmitted from the animal to the fœtus *in utero*, and persists in the young for some time after birth. Tizzoni and Cattani have made white mice immune by the serum of the blood taken from frogs and pigeons which are unsusceptible to tetanus; but Kitasato, experimenting with the blood of chickens, has contested their assertions. Kitasato has rendered rabbits immune from tetanus by injections of iodoform. Tizzoni and Cattani state that rabbits from which the spleen has been removed cannot be made immune. Behring, Frank, Tizzoni, and others prepared a serum containing the antitoxine from animals made artificially immune and used it on human subjects. This serum acts chiefly upon the toxines of the tetanus bacillus, diminishing their poisonous action. The antitetanic serum has been employed in a large number of cases of tetanus, but it is not yet possible to give a final opinion regarding its therapeutic value. Some authorities, including Roux, Vaillard, and Doyon doubt the possibility of curing by antitoxine a case of tetanus that has once developed, but they admit that the outbreak of the disease can be prevented by prophylactic inoculation.

Disinfection of Objects Infected with the Tetanus Poison.—The disinfection of all objects infected with the tetanus poison is best carried out by subjecting them to the action of steam at a temperature of 100° C. to 130° C. (212° to 266° F.), or by boiling them in a one-per-cent. aqueous solution of soda. For the disinfection of hospital wards, rooms, etc., Bombicci recommends nascent chlorine, while a ten-per-cent. solution of chloride of lime can be used for stone walls, or, better, a mixture of ten parts of chloride of lime, twenty-five parts of quicklime, and one hundred parts of water. Fluid coal tar is excellent for wooden walls. Tizzoni and Cattani recommend a mixture of one per cent. bichloride of mercury, five per cent. carbolic acid, and five tenths per cent. hydrochloric acid for disinfecting the hands of the surgeon.

Tetany.—*Tetany* is a condition characterised by a peculiar irritability of the anterior horns of the spinal cord, causing tonic contractions, particularly of the hands and feet. It is sometimes acute, sometimes subacute, sometimes chronic, and may be of a benign nature or absolutely fatal. Numerous investigations have increased our knowledge of the clinical forms, but the etiology is still not fully known. Pfeiffer distinguishes the following varieties: 1, the epidemic or endemic (Jaksch's acute recurrent form); 2, the tetany of pregnant and nursing women; 3, the tetany following removal of the thyroid gland; 4, the tetany from poisoning by ergotine,

chloroform, etc. (toxic tetany); 5, the tetany after infectious diseases; 6, the tetany resulting from gastro-intestinal affections; 7, the tetany in constitutional diseases. The variety which is of chief interest to the surgeon is that following removal of the thyroid gland (for particulars see Regional Surgery—Goitre). Whether certain micro-organisms can be looked upon as the cause of tetany, particularly the epidemic form, is still a question.

The Clinical Course of Tetanus.—The symptoms of tetanus appear after a variable period of incubation. According to Rose, to whom we are indebted for an excellent monograph on tetanus, the disease appears in half the cases in the second week after the injury, in one third of the cases in the first week, in one fifth of the cases in the third to fourth week, etc. The first symptom is usually a peculiar stiffness and spasmodic contraction of the muscles in the vicinity of the injury. Two to four days later it is noticed that the patient cannot open the mouth properly, and he complains of pain in the muscles of mastication. At the same time there is usually a high fever, though in the less acute cases the fever may be absent. As a result of the cramp-like contraction of the facial muscles, the countenance assumes a peculiar rigidity. There soon follows a certain amount of stiffness of the neck, with tetanic spasms lasting a few or several minutes, and affecting at one time the trunk and at another the extremities; they are very painful, and are excited by the slightest external irritation—for example, by touching the patient, by a draught of air, a noise, etc. Many of the muscles become firmly and permanently contracted. The tetanic contractions are caused by the action of the tetanus poison both upon the central nervous system and the peripheral nerves. This is probably a reflex action due to stimulation of the sensory nerves (see page 306). The fever in tetanus is usually high, the rise in temperature not infrequently reaching 41° to 42° C. (105.8° to 107.6° F.), or even 43° to 44° C. (109.4° to 111.2° F.), while after death there is sometimes a further rise to about 45° C. (113° F.). This excessive increase in body heat is essentially the result of muscular contraction, as was also proved by Leyden's experiment, in which, within two hours, the temperature of a dog was made to rise from 39.6° C. (103.2° F.) to 44.8° C. (112.6° F.), simply from the frequently repeated muscular contraction caused by powerful electrical stimulation of the spinal cord. The patients usually retain perfect consciousness, and are bathed in sweat. The urine contains albumen, probably as a result of the tetanic contraction of the renal arteries. There are also cases which may run a rapidly fatal course and yet be unaccompanied by fever. In these there is an extensive muscular rigidity, particularly about the head and trunk, the patients hold themselves perfectly stiff,

and there are none of the above-described muscular contractions alternating with a momentary abatement of the rigidity.

Acute tetanus is usually fatal. Death may occur within twenty-four hours from the beginning of the disease, or after the lapse of four to five days. There is also a subacute or chronic form of trismus or tetanus which ordinarily is not accompanied by fever. Sometimes the tetanus remains limited to the muscles in the neighbourhood of the injury, affecting perhaps the arm alone, or the injured leg, or the muscles of the head.

Head Tetanus.—Rose, Bernhardt, and Güterbock state that the so-called head tetanus occurs after injuries in the region of the distribution of one of the twelve cranial nerves. It is distinguished particularly by tetanic contractions of the muscles of mastication—by trismus, as it is called—which is combined with facial paralysis and spasm of the muscles of the pharynx, as in hydrophobia, and hence is sometimes given the name of tetanus hydrophobicus. In a certain number of cases spasms alone appear, and in others the spasms are accompanied by paralytic manifestations. The paralyses occur chiefly in the distribution of the facial nerve, less often in nerves of the eye, while the motor branches of the fifth remain unparalysed, and, on the contrary, take a prominent part in the contractions (Brunner). The rigidity then descends to the neck, trunk, and extremities. The contractions begin on the same side as the injury and are stronger here. The paralytic manifestations occur regularly on the same side as the injury; and in case the injury is in the median line the facial paralysis may be present on both sides. The paralysis of the facial nerve, according to Rose's view, is caused by compression of the swollen nerve in the aqueductus Fallopii, but this cannot always be demonstrated in the post-mortem examination. Head tetanus is not always fatal, particularly chronic cases, which Klemm's statistics show may last from four to twelve weeks, and are much more apt to terminate favourably than the acute form of the disease. Güterbock and Bernhardt collected fourteen cases with four recoveries. Klemm had one case of chronic tetanus hydrophobicus, and collected the reports of twenty-four others, seven of which recovered, six of these being chronic.

Pathology of Tetanus.—The *anatomical changes* in *tetanus* are slight. The microscopical examination of the spinal cord and the neighbouring peripheral nerves shows an extensive proliferation of the cells. Monastyrski found half-moon-shaped extravasations of blood in the interstitial connective tissue of the spinal cord and peripheral nerves, and a granular infiltration of the nerve cells.

Prognosis of Tetanus.—The prognosis of tetanus depends chiefly upon the time of incubation and the virulence and number of the bacilli or spores (Beck). The acute cases, with a short period of incubation, usually run a fatal course, while the subacute and rare chronic cases have a better prognosis. Furthermore, the outcome is not always fatal in those cases where the tetanus is confined to the muscles of the injured limb or to the head (hydrophobic tetanus). The earlier tetanus is recognised and treated properly the better the prognosis. According to Rose, the mortality of tetanus is 88 per cent.

Treatment of Tetanus.—Treatment in acute tetanus, if it is fully developed, is of little effect. The treatment is local and constitutional. The wound should be treated antiseptically, and if possible its primary focus should be destroyed. Wounds that have been soiled by dirt or other material should be thoroughly cleansed and disinfected. As the tetanus bacillus is anaërobic, the wound should be thoroughly opened so as to allow free access of the air, and the infected tissues should be removed with the knife, scissors, sharp spoon, or thermo-cautery. Tizzoni and Cattani recommend, for the disinfection of wounds in which there is fear of the development of tetanus, a one-per-cent. solution of nitrate of silver, which destroys the bacilli and the spores very rapidly and certainly—in one minute. In suitable cases early amputation of the injured member is advisable. Recovery has followed in some cases, and in others amputation was unsuccessful in saving life. Especially in tetanus following injuries of the extremities, attempts have been made to arrest the disease by exposing and stretching the principal nerve trunks—the sciatic, for instance—which supply the injured portion of the body, and Verneuil, Kocher, and others have reported cures by this treatment. The good obtained from nerve-stretching in infectious tetanus is certainly open to doubt (§ 97). With the local treatment we combine injections of antitetanic serum. A number of cures from the use of the serum have already been reported. The injections are useful chiefly in the incubation period, or before the disease has fully developed.

The remainder of the treatment for tetanus is purely symptomatic. Subcutaneous injections of morphine are often used, accompanied by the administration of chloral hydrate (three to five grammes *pro die*) by the rectum, or large doses of chloral hydrate or bromide of potassium may be given internally, two grammes of chloral hydrate being alternated with the same amount of bromide of potassium every two hours. Kane states that, of two hundred and twenty-eight cases treated with chloral hydrate, one hundred and thirty-four recovered and ninety-four died. Of ninety-three treated with chloral hydrate in combination with other remedies, thirty-three died. The most efficien

means for quieting a patient during a paroxysm is to administer chloroform by inhalation; but after the cessation of the narcosis the muscular spasm immediately recurs. Curare, the Indian arrow poison, which has the power of paralysing voluntary muscles, is an exceedingly valuable remedy, though very inconstant in its effects on account of its variable chemical composition. The success of the curare treatment has not, however, been very encouraging. Its concentration varies within wide limits. Curare can be injected in the dose of about 0.015 to 0.05 gramme every quarter to half to one hour. Karg has curarised patients (by subcutaneous injection) till respiration became paralysed, after previously performing a prophylactic tracheotomy for facilitating artificial respiration; but all the cases treated in this way terminated fatally. It is a better plan to combine the administration of narcotics with injections of curare. Inhalations of amyl nitrite (five drops twice a day) have been used with success. Bacelli has obtained satisfactory results by injections of carbolic acid (0.01 gramme every hour). Sormani recommends iodoform. According to the latter's experiments, the tetanus poison is neutralised by iodoform, or by the iodine derived from it; and by treating the wound with iodoform during the period of its incubation tetanus can be prevented. He states that mice inoculated simply with earth died of tetanus in less than three days; but if the earth used in the inoculations was first mixed with iodoform the animals remained unaffected by the disease. Pure cultures are not changed when iodoform is added to them, but are killed in one minute by the addition of a one-per-cent. solution of nitrate of silver (Tizzoni, Cattani). Sormani also recommends iodol, a two-per-cent. acid solution of bichloride of mercury, and chloral with camphor. The further treatment of the disease consists in careful isolation of the patient, and in keeping away from him every sort of external irritation or disturbance, particularly during the stage when the muscular spasms are a prominent symptom.

De Renzi has succeeded in curing four out of a total of five cases of tetanus by securing to the patient absolute rest, which is the very best curative agent at our disposal. De Renzi places the patient with tetanus—the ears having been plugged—in a room which is completely isolated, absolutely quiet, and darkened. All the necessary manipulations in the care of the patient are performed, as far as possible, in the dark. The nourishment is entirely fluid. When the pain is severe De Renzi gives belladonna and ergot internally.

§ 74. **Septicæmia.**—The term *septicæmia* is given to a poisoning of the body (intoxication) which, as a rule, rapidly terminates in death,

and is not characterised by the formation of such metastatic suppur tive processes as occur in the disease called pyæmia (pus poisoning which is closely related to it. Septicæmia is usually found in conjunc tion with putrefactive (gangrenous) changes in a wound or inflammatory focus, though it may sometimes have an intestinal or pulmonary origin. Occasionally the point of entrance of the infection cannot be found (cryptogenetic septicæmia.) It is often perfectly impossible to make a sharp distinction between pyæmia and sepsis, as the two diseases are frequently found in combination, both clinically and anatomically, and hence the term *septicopyæmia.* Examination of the blood for bacteria is of great importance for the etiology and prognosis of sepsis and pyæmia. Absorption of the toxines alone seldom causes death; bacteria can usually be found in the blood of the fatal cases.

Etiology of Septicæmia in Man.—Virchow, Billroth, and others produced septicæmia by injecting decomposing substances into the vascular system and tissues of animals, and the discoveries in fermentation and decomposition which were made about the same time helped to shed light upon the importance of lower organisms in the production of sepsis. Then Panum demonstrated that analogous septic diseases could be excited by using decomposing fluids which had been boiled after the fungi existing in them were removed. This theory of the origin of septicæmia, partly from bacteria and partly from fluids free of bacteria, is now being still further elaborated, so that at present we distinguish two principal forms of septicæmia, one caused by fungi and the other by soluble chemical poisons. The septicæmia due to the presence of bacteria is an infectious disease capable of transmission to other animals; in other words, the blood of animals having this kind of sepsis will produce the same disease when inoculated into healthy animals. The virulence of the blood increases each time it is taken from an animal having the disease and inoculated into a healthy one.

In the second form of septicæmia the blood contains dissolved in it chemical poisons or gases, the poisonous products of the metabolism of the fungi, and it is not infectious any more than the blood of an individual suffering from strychnine or prussic-acid poisoning.

Between the two forms of septicæmia the one due to toxines and the other to bacteria, there are numerous transition and combined forms; in other words, bacteria of every description are sometimes found in the blood of those suffering from poisoning by the chemical products of bacterial metabolism.

The changes which take place in decomposition are of great importance for an understanding of the etiology of septicæmia. It has been mentioned that in the decomposition excited in albuminous bodies by bacteria, various substances are formed, the chief of which are peptones and similar bodies, nitrogenous bases (leucine, tyrosine, amine), organic fatty acids, aromatic products, colouring matters, and particularly poisonous toxalbumens, and certain alkaloids to which have been given the name of cadaver alkaloids or ptomaines. The latter possess intensely poisonous properties. It had long

been known that toxic bodies were present in the products of decomposition, as Panum, in 1863, had isolated from putrefying substances his putrid poison. Bergmann and Schmiedeberg obtained a crystalline body, sepsine, Billroth discovered another, etc. Selmi was the first to recognise the nature of these bodies, and he gave them the name of cadaver alkaloids or ptomaines. Brieger and others have obtained several ptomaines in a pure state, such as collidine, peptoxine, neurine, neuridine, choline, etc., and have investigated their action upon animals. Paterno, Spica, and others found that ptomaines are also a product of normal metabolism, though, of course, they are formed in small amounts. They are hence not exclusively decomposition-products of the albuminoid bodies in the presence of bacteria. The poisonous ptomaines are called toxines. Bergmann and Angerer have proved that febrile diseases similar to septicæmia can be produced by non-bacterial poisons such as ferments. In a case of septic (putrefactive) intoxication occurring without the presence of micro-organisms in the blood, there will somewhere be found a focus of suppuration or some decomposing pus or blood, the decomposition being due to micro-organisms, particularly the various kinds of bacilli. If the focus of suppuration is removed early enough recovery may take place. In these foci of suppuration or gangrene there will be not only the bacteria of decomposition, but many others, such as pyogenic staphylococci, streptococci, and different bacilli.

Septicæmia in man is caused sometimes by bacilli and sometimes by cocci (*Streptococcus pyogenes*, *Streptococcus septicus* Flügge, *Staphylococcus aureus*). In the septicæmia due to progressive gangrenous emphysema various bacilli have been demonstrated. Chameon, Rosenbach, and others found the same bacilli which Koch proved to be the cause of malignant œdema—a disease running a rapidly fatal course in mice, guinea-pigs, and rabbits.

These œdema bacilli (Figs. 304, 305), which Pasteur formerly designated as *vibrions septiques*, were described on pages 339 and 340. It is interesting to note that the symptomatic anthrax occurring endemically in cattle is produced by similar bacilli, and that their multiplication in the subcutaneous cellular tissue causes inflammatory swelling with the evolution of gas. Furthermore, in hæmorrhagic septicæmia many kinds of bacilli have been found. Lubarsch observed a case of septic pneumonia in a newborn child which died two days after birth. He cultivated from the lungs and spleen rod-shaped organisms which in the main corresponded with Gärtner's *Bacillus enteritidis*. Sepsis results in some cases from endocarditis with old or recent vegetations upon which streptococci are deposited from the blood, giving rise to infected emboli.

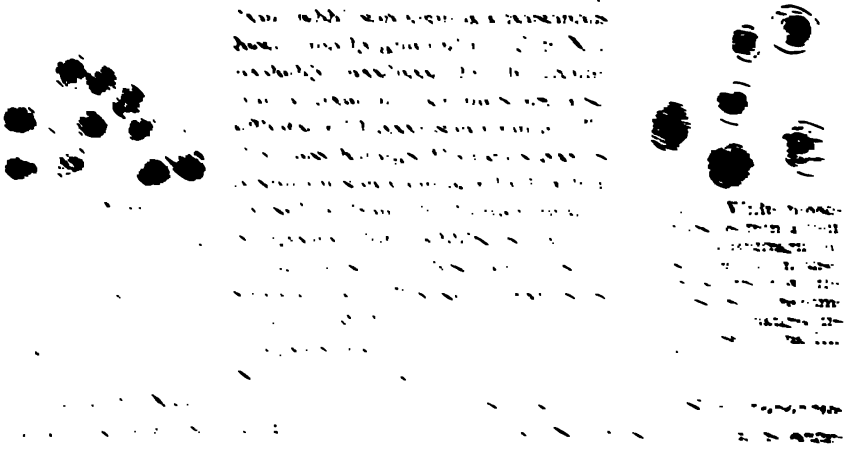
Experimental Septicæmia in Animals.—Thanks to Robert Koch, we possess a more accurate knowledge of human septicæmia on account of this investigator's experiments upon animals. There is a toxic septicæmia (septic intoxication), and a septicæmia which is bacterial in its nature (transmissible septic infection). Toxic septicæmia occurs after the injection of large amounts of decomposing substances into the subcutaneous cellular tissues. Immediately, or soon after the injection, there ensue restlessness, weakness, cramps, often vomiting, finally paralysis, and not infrequently death follows in a few hours from paralysis of respiration. No bacteria are found in the blood or internal organs. If decomposing fluids, with the bacteria of decomposition,

are kept for twenty-four hours in the incubator at a temperature of 40° to 41° C. (104° to 105.8° F.) and then used for injection, the poisonous effects are

FIG. 311. Bacilli of septicæmia in a vein of the diaphragm, taken from a septicæmic mouse. White blood corpuscles, some containing bacilli, and some changed into masses of bacilli. × 700. (Koch.)

very pronounced, but if the fluid is treated in the same way for forty-eight hours no effects follow its injection.

In the bacterial septicæmic infection great numbers of bacteria will be found in both the blood and the tissues. Koch showed that there were two kinds of bacterial septicæmia: the septicæmia of mice and the septicæmia of rabbits, both of which are caused by bacilli. The bacilli of mouse septicæmia are very fine rods (Figs. 311, 312), like the bacilli of swine erysipelas; while the bacilli of rabbit septicæmia, recently described by Gaffky, are [illegible] allied to the bacteria of chicken cholera, the bacilli of [illegible] and the bacilli of fowl cholera. Hueppe proposes to call [illegible] the bacteria of septicæmia hæmorrhagica. There are, [illegible] bacteria, septicæ-



sionally transmitted from parrots to man. Lepetit found as its cause a small coccus which he obtained from the blood and made pure cultures of. He found the *Staphylococcus aureus* and *citreus* in the lungs.

Bacteria of Decomposition.—Hauser has taught us the morphology and biology of three kinds of bacteria causing decomposition, and called by him *Proteus vulgaris*, *Proteus mirabilis*, and *Proteus Zenkeri*. From small rods similar to Cohn's *Bacterium termo* there develop in proper nutritive media longer rods and screw-shaped filaments, which, after exhausting the nutritive medium, change into short rods and spherules, which are probably spores. These three kinds of bacteria, isolated from decomposing substances, are capable of exciting decomposition, while the filtrate freed from bacteria did not have this power (saprogenic). The investigations about their pathogenic properties and their relationship to septicæmia revealed the fact that these three bacteria evolved, by exciting decomposition of animal tissue, a violent chemical poison, which, when introduced in very small amounts into the blood and lymphatic vessels of small animals, caused the death of the latter with every symptom of putrid intoxication. These bacteria, which are saprophytic, are not themselves pathogenic—that is, they are not capable of developing within the living body. According to Brunner, however, the *Proteus vulgaris* is frequently of importance in the most acute cases of puerperal sepsis; it is possible that, like the *Bacillus coli communis*, it passes from the rectum into the female genital tract. According to E. Levy, the *Proteus vulgaris* (Hauser) is to be looked upon as a germ of decomposition which has a variable poisonous action, and when injected subcutaneously into dogs, mice, and rabbits it causes the typical picture of sepsis, and particularly an acute hæmorrhagic gastro-enteritis. A number of the cases of meat poisoning are caused by this bacillus proteus (Hauser).

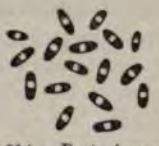


Fig. 314.—*Bacterium septicæmiæ hæmorrhagicæ* (Hueppe), bacteria of chicken cholera, rabbit septicæmia, etc. Diagrammatic and much enlarged.

Fig. 315.—Pure culture of the bacterium of hæmorrhagic septicæmia (Hueppe). × 1,000.

Ferment Intoxication and Septicæmia.—Semmer, Rossbach, and Rosenberger have made experiments which show that after the injection of ferments or sterilised septic blood the animals thus treated will die of sepsis, from the development of bacteria in the blood. If these experiments are free from error, it seems to prove that the properties of the blood are so changed by the injection of the above-named substances that it is rendered possible for bacteria to develop in it—a thing which would be impossible if normal conditions existed in the blood and tissues. But there is some reason to doubt that the substances injected in these experiments were actually free from all contamination by bacteria. Bergmann and Angerer have made some interesting discoveries as to the relationship of ferment intoxication to septicæmia. It is well known that Birk and others, by transfusing blood containing ferment, or by injecting fibrin ferment into the blood, obtained in the animals experimented upon, both during life and after death, the same phenomena which occur after the

introduction of fluids which are decomposing or rendered foul by bacterial vegetation. The changes consist essentially in a more or less extensive disintegration of the white blood-corpuscles, with a secondary formation of fibrin in the capillaries, the large pulmonary vessels, and in the heart. Bergmann and Angerer excited the same changes by injecting large doses of sterilised, transparent, aqueous solutions of pepsin and pancreatin. The severe ferment intoxications run a rapidly fatal course, presenting the picture of intoxication by decomposing substances. The pure ferment consequently acts in a manner similar to the pathogenic bacteria—that is, mainly by destroying the white blood-corpuscles. These investigators were unable to confirm the above-mentioned statements of Rosenberger and Rossbach, that bacteria can develop as a result of the presence of sterilised ferment solutions in the blood.

Occurrence of Septicæmia.—Septicæmia in man, since the antiseptic method of treating wounds has come into general use, is of much less frequent occurrence than was formerly the case. Antisepsis, carefully carried out in every operation and in the subsequent treatment of every wound, is the best guarantee against the occurrence of septicæmia. If septicæmia should make its appearance after an operation upon healthy tissue, it is a proof that there has somewhere been a transgression of the rules of asepsis. The septic poison, the micro-organisms, may gain access to the wound in many different ways—for instance, at the time the injury was received, or by infected instruments, unclean fingers, etc.

Pathological Changes in Septicæmia.—The pathological changes in septicæmia consist, in the first place, in the local changes at the point of infection and the surrounding parts, which will be more minutely described when we come to the symptomatology. The most constant change is found in the blood after death. It is dark-coloured, like tar, prone to rapid decomposition, and not infrequently has an acid reaction (carbonate of ammonia). According to Grawitz the blood is noticeably thin; if the percentage of solids in the blood was lowered from 21 per cent to 15 per cent. or less, death always occurred. The above-mentioned micro-organisms will be found in the vessels and blood, and in the tissues of the different organs, though in cases of pure intoxication the micro-organisms will not have a general distribution throughout the body, but will be present only in the focus of infection. The disintegration of the white and, to a less extent, of the red blood-corpuscles, brought about by the micro-organisms or by the products of their metabolism, is characteristic. The bacteria are present in the white blood-corpuscles, in which they are scattered through the system, and finally change the leucocytes into masses of bacteria (Figs. 311, 313). As a result of the disintegration of the

white blood-corpuscles, the blood possesses an increased power of coagulation. In consequence of the changes in the composition of the blood and the alterations in the walls of the vessels, allowing their contents to escape through them, there arises a tendency to small and large hæmorrhages in the gastro-intestinal tract, in the mesentery and omentum, in the spleen, endocardium, pleura, kidneys, bladder, and, in short, in all the different organs. The changes occurring in the heart and lungs are not constant, there being sometimes a general pleurisy and sometimes symptoms of pericarditis. In the intestinal canal there is frequently an extensive enteritis, taking the form of a catarrhal swelling with ecchymoses, and the formation of ulcers, as in a dysenteric inflammation. The spleen is almost always large and soft, and the liver is likewise somewhat enlarged, congested, and friable. The kidneys are increased in size, the parenchyma is in the stage of cloudy swelling, and there is a catarrhal change in the uriniferous tubules. The above-mentioned micro-organisms will be found most abundantly in the kidneys, and chiefly in the capillaries of the glomeruli and in the afferent vessels. The changes in the internal organs are sometimes very slight. Diffuse metastatic inflammations, embolic infarcts, and foul abscesses also occur in septicæmia, especially when the latter is combined with pyæmia (pyo-septicæmia); but they are by no means so frequent or so characteristic of septicæmia as are the metastatic suppurations for pyæmia.

The Clinical Course of Septicæmia.—The *symptoms* of septicæmia are, for the most part, characterised by the presence of a high and generally continuous fever, and by a number of inflammatory processes. The two different forms of septicæmia—distinguished in respect to their etiology, the putrid or septic intoxication due to the products of bacterial metabolism, and that due to the presence of bacteria—cannot clinically be sharply differentiated, and in man, as we have stated before, they not infrequently occur in combination. It is impossible to describe the symptoms of septicæmia so as to include all its forms.

The wounds which are capable of giving rise to septicæmia may be fresh or granulating. Every wound, no matter how small, can be the starting-point for septic infection. The mode of development of the wound infections was described at length in § 66. The local manifestations at the point of the injury vary greatly, and they may, in fact, be entirely absent, as in the cases of septicæmia, which run a very acute course. These are characterised by a rapid febrile intoxication of the whole system, which occurs before there are any local symptoms in the wound. In the worst cases there is a gradual clouding

of the mind, followed by stupor and death within the first two three days.

The febrile movement is not characteristic in septicæmia; in fac there are forms of the disease which run their course without any fever at all. On the other hand, the frequency of the pulse is always noticeably increased (Fig. 316). If the ordinary wound-fever, occurring after open injuries from the absorption of the products of decomposition, is looked upon as a septic intoxication, it must be admitted that we frequently meet with transient abortive forms of septic intoxication, which are marked by a moderate rise of temperature to about 39° C. (102.2° F.), and terminate favourably in a few days without giving

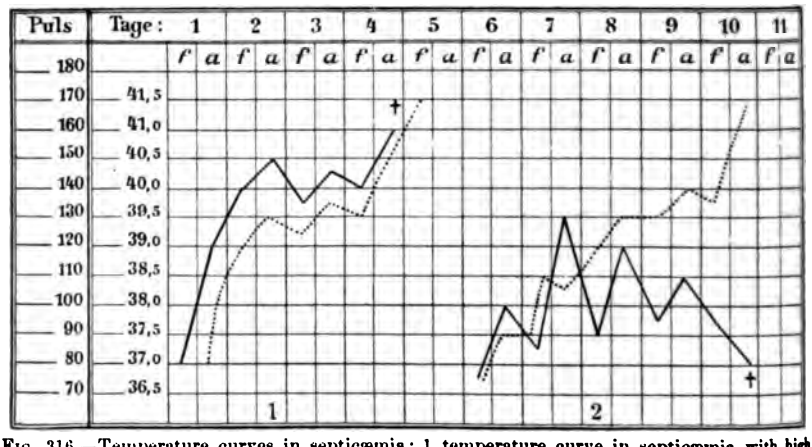


FIG. 316.—Temperature curves in septicæmia: 1, temperature curve in septicæmia, with high fever; death with a temperature of 41° C. (105.6 F.), and pulse of 170 on the third day after the operation (laparotomy); 2, temperature curve in septicæmia with a slight rise of temperature; death on the fourth day after the injury (gun-shot wound), preceded by a subnormal temperature and very rapid pulse.

rise to any appreciable complication in the wound or in the internal organs. This simple septic fever is of very common occurrence, while it is relatively seldom that we meet with the above-mentioned severe cases of septic intoxication which run a rapidly fatal course. In discussing fever in general, we learned that the latter may be caused by the absorption of substances which were not decomposed, such as fibrin ferment, etc.—a condition which Volkmann and Genzmer have designated as wound-fever. Consequently our present knowledge of the etiology of fever makes it impermissible to look upon every rise in temperature in those who have been injured as a septic fever.

All cases of general sepsis in which the inflammation is plainly spreading from the point of infection have, in general, an unfavourabl prognosis. The severity of the constitutional symptoms and the e:

tent of the local inflammatory process vary here, too, very much, the latter showing all the steps from a mild lymphangitis to a violent septic phlegmon or an acute septic gangrene. In this class belong the cases of septic infection which arise from very slight injuries, such as are not uncommon on the fingers of surgeons after operations upon abscesses, decomposing tissue, etc., from infection by putrefying matter. After twelve to twenty-four hours there is a chill, and the temperature rapidly rises to 39.5° C. (103.1° F.) or 40° C. (104° F.) and higher, the small wound on the finger becomes painful and is inflamed, the epitrochlear and axillary glands swell, and red streaks appear on the arm (septic lymphangitis). By the next day, if proper treatment is employed, the septic infection may have run its course, or recovery may take place with the formation of pus at the point where the injury was received, and with the development of circumscribed abscesses in the epitrochlear and axillary glands, or death may follow from general septic poisoning. In other instances, the septic inflammation starting from the wound is severe, and leads to an extensive, rapidly spreading cellulitis, which is accompanied by high fever, as described on page 338. Rarely, and then particularly after severe traumatisms, such as a "run-over" accident, a rapidly advancing, putrefactive inflammation will develop with the evolution of gas in the tissues, usually terminating in death within the first forty-eight hours. The gangrene of the tissues in such cases may in the first place be caused by the injury alone, and then, in addition to the local traumatic gangrene, there is added a rapidly extending decomposition, due to the entrance of the germs of decomposition, which may spread, and involve the entire extremity. Sometimes this traumatic origin of the gangrene due to contusion of the tissues can be excluded, and yet there will be a rapidly spreading gangrene, with decomposition and the evolution of gas. This is sometimes the case in snake bites. The acute purulent œdema of Pirogoff and the *gangrène foudroyante* of Maisonneuve belong to those worst forms of septic inflammation. The affected extremity is usually excessively swollen, partly from œdema and partly from the gases produced by decomposition. At the same time there is given off a foul odour, and a crackling emphysema of the skin radiates in all directions from the wound. The muscles become changed into a reddish-brown mass full of bubbles of gas. Coma and death follow in a few days, usually preceded by an increase in the œdema. This progressive gangrenous emphysema (*gangrène gazeuse*)—which, by the way, is of very infrequent occurrence since the introduction of antiseptic methods—is caused by bacilli similar to those which Koch identified as the cause of malignant œdema in mice, guinea-pigs, and rabbits. Progressive gangrenous emphysema

occurs in conjunction with compound fractures, or any deep wound into which earth or some other material containing the œdema bacilli has penetrated.

The other symptoms of septicæmia referable to the internal organs are caused by the general septic infection. Usually the spleen is plainly enlarged, and very often the liver also. Not infrequently there is jaundice, generally of a hæmatogenous nature, as a result of the disintegration of the red blood-corpuscles caused by the micro-organisms or their products. There are usually gastro-intestinal disturbances, which in the severer forms of septicæmia give rise to a diarrhœa which is sometimes feculent, sometimes mucous, or even bloody-diphtheritic in character.

The urine ordinarily contains albumen. The diffuse inflammations of the pleura, the pericardium and endocardium give rise to marked symptoms only in exceptional cases. There are not infrequently exanthematous eruptions of the skin, which take the form of blebs or pustules, or resemble urticaria, measles, or scarlet fever. These eruptions are caused in part by the bacteria (bacterial metastases in the skin) and in other cases they are to be explained as angioneuroses due to the action of bacterial toxines (Meyer). Hæmorrhages in the skin and the internal organs are sometimes a prominent symptom (hæmorrhagic septicæmia, see also page 375). Veins and arteries may be opened by abscesses, leading to dangerous hæmorrhages.

Prognosis of Septicæmia.—The prognosis of septicæmia is, in the pronounced cases of bacterial septicæmia, for the most part unfavourable. The cases of intoxication by decomposing substances in which, by proper treatment, we can remove from the body the focus of infection, have relatively the best prognosis. After this procedure has been accomplished the absorption of the products of bacterial metabolism ceases, and with it also the poisoning. But it is important to bear in mind that a patient may apparently recover from septicæmia by encapsulation of the infectious matter, and yet, after the lapse of a longer or shorter time, it may again enter the circulation, being set free, perhaps, by some slight trauma or by a violent muscular contraction, and cause the death of the patient. The experiments of Grawitz, Behring, and others make it seem probable that the powers of the organism for withstanding septic intoxication are weakened principally by the extensive disintegration of the red blood-corpuscles brought about by the toxic substances.

Diagnosis of Septicæmia.—In the diagnosis of septicæmia, the behaviour of the original wound or injury and the inflammatory manifestations in it, the presence of decomposition of the blood, wound secretion, or pus, and the presence of fever, and particularly the increased frequency of the pulse, are all important. In those cases of septicæmia in which, without noticeable local inflammatory symptoms, there occurs within a few hours of the reception of the injury a severe fever, the diagnosis can usually be cleared up by

getting an exact history of the injury. A small and very rapid pulse is exceedingly important in making the diagnosis of septicæmia. The greatest diagnostic difficulties will be met with in those cases in which no source of infection can be found, in the so-called cryptogenic septicæmia or septico-pyæmia, the origin of which can only be ascertained during the course of the disease or at the post-mortem examination. Wagner has published a very instructive account of a number of cases of this kind.

The So-called Surgical Scarlatina.—In speaking of the symptomatology of pyæmia and septicæmia, we mentioned the occasional occurrence of exanthematous eruptions in the skin, particularly those which resemble the eruptions of measles and scarlet fever. Surgical scarlet fever, as it is called, has been described by Thomas, Riedinger, and Hoffa. It is sometimes a purely vasomotor disturbance. In addition to this eruption of septicæmia, pyæmia, and erysipelas, due to vasomotor disturbance, there is also a real scarlatina which occurs, particularly in children, after operations and the reception of wounds. In such cases the poison of scarlet fever passes directly from the wound into the general circulation. E. Koch collected twenty-six cases of true scarlatina following operations and the reception of wounds among the patients of the children's hospital at Basel, and he states that the period of incubation in this wound scarlet fever is shorter than in the usual non-surgical form. This surgical scarlatina is probably due mainly to streptococcus infection.

Treatment of Septicæmia.—The treatment of septicæmia consists, in the first place, in treating any injury which may be present with the greatest surgical care. Every infectious-wound disease, and consequently septicæmia, can be avoided by antisepsis or asepsis if strictly carried out. If fever follows an injury or an operation, the wound should be most carefully examined, and any retention of decomposing blood, of the wound secretion, or of pus, should be immediately remedied by incision and drainage, and this should be followed by disinfection with a 1 to 1,000 solution of bichloride of mercury or a three- to five-per-cent. solution of carbolic acid. The special treatment for local inflammation and suppuration is described in §§ 67–72. In septicæmia which is the result of a severe septic phlegmon with extensive gangrene, it may not infrequently be necessary to sacrifice an entire limb, by amputation or disarticulation, to save the life of the patient. But it should be borne in mind that in an extensive septic cellulitis, numerous free incisions, followed by thorough disinfection of the infective focus thus freely exposed, may be sufficient to answer every purpose; though, on the other hand, amputation should not be too long delayed, as the patient may even after that die of septicæmia. The rest of the treatment is wholly symptomatic; there is no effective remedy for counteracting septic constitutional infection. The treatment of the fever is conducted on the rules laid down in § 62. If the skin of an infected patient is dry, Billroth recommends that the excre-

tion of the poisonous substances be hastened by exciting pronounced diaphoresis, either by placing the patient in a warm bath for an hour, or by wrapping him up in warm blankets, or by administering large quantities of a hot drink, etc. As a matter of fact, we know from the experiments of Brunner and others that the bacteria are excreted in the sweat. The septic diarrhœa is combated with opium, tannin, subnitrate of bismuth, acetate of lead, enemas of starch paste containing tannin, opium, etc., but unfortunately they are usually without much effect. The diet of the patient should be one which is easily assimilated, and as nutritious as possible. Alcohol in the form of strong wines or whiskey should be given freely. Transfusion, which has been used by Hueter in the treatment of septicæmia, is not to be recommended.

§ 75. **Pyæmia (Pyohæmia) or Pus Poisoning.**—Pyæmia or pyohæmia (from πῦον, pus, and αἷμα, blood) was, until recently, understood to mean an infection by pus, a pus poisoning, caused by the presence in the blood of the elements of pus. In general, pyæmia is characterised by the development of multiple foci of suppuration (metastases) in the different organs, as a result of the wide distribution of the pyæmic poison, and by an intermittent type of fever. It has been stated before (page 370) that it is often impossible to draw a sharp distinction between pyæmia and septicæmia, and that both of these diseases, clinically as well as anatomically, frequently occur together (septicopyæmia). Consequently it is becoming more and more a common practice to make no attempt at distinguishing between septicæmia and pyæmia, either clinically or anatomically. It would be simpler to include both diseases under one name, such as pyosepticæmia or septicopyæmia.

Etiology of Pyæmia—Micro-organisms.—Koch has produced experimentally in rabbits a pyæmia which is similar to the pyæmia occurring in man. He states that this pyæmia of rabbits is excited by a specific coccus which differs from all other cocci, and in particular from the coccus of the cheesy pus found in rabbits.

It used to be believed that the pyæmia of man was due to a specific micro-organism, but this theory has been proved to be incorrect; and, in general, there are found in pyæmia the same micro-organisms as in septicæmia (see pages 370–374), which is a proof that the two diseases cannot be considered etiologically distinct. The common pus cocci are the ones most constantly present in pyæmia (see pages 327–330). Any acute abscess may give rise to the disease. Under ordinary conditions the abscess is cut off by the inflammatory infiltration surrounding it from the adjoining healthy parts, so that the cocci cannot find their way out into the tissues and circulatory fluids of the body. If, however, the system is not protected in this manner, if the suppurating area is subjected to a certain amount of pressure

or if there is any considerable new addition of cocci to those already present, a general systemic poisoning from the cocci, with a constitutional febrile disease and the formation of suppurating foci in all the different organs—in other words pyæmia—is easily produced. Clinically there are two main groups or forms of the pyæmic process. In one there is a large focus of suppuration, possibly in a joint or following a compound fracture, and starting from this focus there is a continuous invasion of the whole body by cocci, accompanied by a hectic fever and followed by death. In the second group of cases there is no large focus of suppuration, but instead there is only some small injury, an insignificant cutaneous abrasion, or a punctured wound, etc.; and following this single infection, there ensues, without any long-continued suppuration at the point of infection, a constitutional pyæmic process and death, though the primary injury may have cicatrised a long time previously. Any collection of pus, whether in the lymph glands or in any of the organs, can suddenly give rise to fatal pyæmia if the bacteria enter the circulation and cause metastases. In this worst form of pyæmia with metastases the ordinary pus cocci are present. Rosenbach found that the most frequent cause of pyæmia with metastases was the *Streptococcus pyogenes* (see page 329), though typical examples of pyæmia have been known to follow infection by other cocci, the *Staphylococcus pyogenes aureus*, for instance. In addition to the pyæmia due to cocci there is also a pyæmia due to bacilli, and essentially the same micro-organisms are present as in septicæmia, and hence the difficulty of distinguishing the two diseases etiologically. Chiari discovered a capsule bacillus to be the cause of pyæmia in some cases. It is similar to Friedländer's pneumonia bacillus and Pfeiffer's *Bacillus capsulatus*. For the pyæmia caused by fungi, see page 373. The course of pyæmia in man, as of the other infectious-wound diseases, varies with the virulence of the infecting micro-organisms, their number, the susceptibility of the individual affected, and the anatomical location and peculiarities of the point of infection. We know that the virulence of the same micro-organism is subject to variation, and that we can artificially weaken this virulence of the septic and pyæmic micro-organism; and it has been proved, by the experiments of Koch, Gaffky, and others, that we can increase their virulence by transmitting the micro-organisms in question from one animal to another of the same species—for example, from man to man.

It occasionally happens that the origin of a pyæmia is not clear during the life of the patient, as is true of septicæmia, and the disease is then called cryptogenic pyæmia or pyosepticæmia. In such cases the focus of the infection which gave rise to the pyæmia can usually be discovered at the post-mortem examination.

The Pathological Changes Occurring in Pyæmia.—The severe poisoning of the whole organism is the predominant feature of septicæmia, but in pyæmia the local inflammatory processes are characteristic. In the first place, micro-organisms will be found in the vessels, in the blood, in all the various organs, and in the metastatic foci of suppuration (Figs. 317, 318). In the blood the micro-organisms are present in the plasma, and particularly in the white corpuscles, which in pyæmia as well as in septicæmia are destroyed in relatively large numbers. The bacterial inflammation of the walls of the

veins, with the consequent formation of thrombi, which, under the influence of the cocci they contain, break down and suppurate, is a characteristic feature of pyæmia (see § 69, Phlebitis). Portions of the infected or suppurating thrombi are torn off and carried away by the blood current and lodge here and there as emboli, possibly in the pulmonary capillaries, and wherever they find lodgment they produce thrombosis and suppuration (metastatic abscesses). Collections of micrococci and metastatic (embolic) abscesses may thus be found in the muscles of the heart, the endo- and pericardium, in the lungs, pleura, brain, liver, spleen, kidneys, in the joints, the marrow of the bones, the muscles, lymph glands, and, in short, in all the different organs. Occasionally a reddening like erysipelas makes its appearance in the skin, but it generally disappears after the lapse of a few days; or there may also be vesicles or pustules. If the pyæmia runs a more chronic course, the pathological changes are less pronounced; the local inflammatory processes, the metastatic abscesses, are not so numerous, or they occur in the stage of convalescence. The marked emaciation of the patient, the fever caused by the changes in the organs (see § 62), and the remnants of the earlier local inflammatory or suppurative processes, are characteristic of chronic pyæmia.

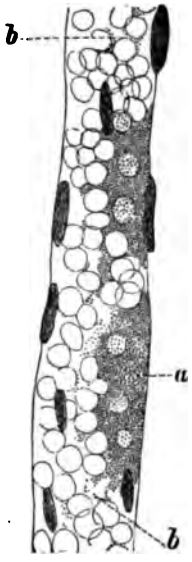


Fig. 317.—Blood-vessel in the cortical substance of the kidney, taken from a pyæmic rabbit: *a*, dense mass of micrococci on the inner wall, containing blood-corpuscles; *b*, *b*, small groups of cocci between the blood-corpuscles. × 700 (Koch).

Occurrence of Pyæmia.—Since the advent of the antiseptic period of surgery, pyæmia has occurred much less frequently than it used to. Before the days of antisepsis many hospitals were notorious for the pyæmia and infectious-wound diseases which raged endemically within them, but now in these same hospitals the antiseptic method of treating wounds has caused the infectious-wound diseases to disappear entirely. The most certain way, then, of preventing pyæmia is to observe the strictest antisepsis and asepsis.

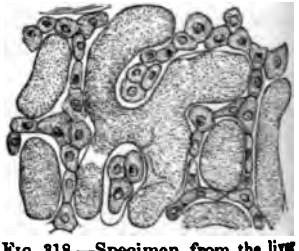


Fig. 318.—Specimen from the liver of a man who died of pyæmia. The capillaries between the liver cells are filled with masses of micrococci.

Clinical Course of Pyæmia.—The symptoms of pyæmia are characterised by the development of collections of micrococci and multiple metastatic abscesses in different organs of the body, and by an intermittent type of fever with intercurrent chills. According to the nature of the wound the cases are divided into two main classes. In the first group there is somewhere a collection of pus—for instance in a joint—or it may be connected with a compound fracture, and from this focus the whole body receives constant invasions by

cocci, and at the same time there is an intermittent fever with intercurrent chills. In the second group of cases the disease originates from the single infection of some small wound, and not from a collection of pus which has been in existence a long time. In this second group the micro-organisms multiply in the system and spread through all parts of it, and wherever they find lodgment they excite inflammation and suppuration. Frequently there is no injury present. In this case the pyæmia has developed from some inflammatory or infectious focus.

The pyæmic fever, which has been carefully studied by Billroth and Heubner, does not, as a rule, follow a regular course, but, in the main, is intermittent—that is, after a marked elevation of temperature

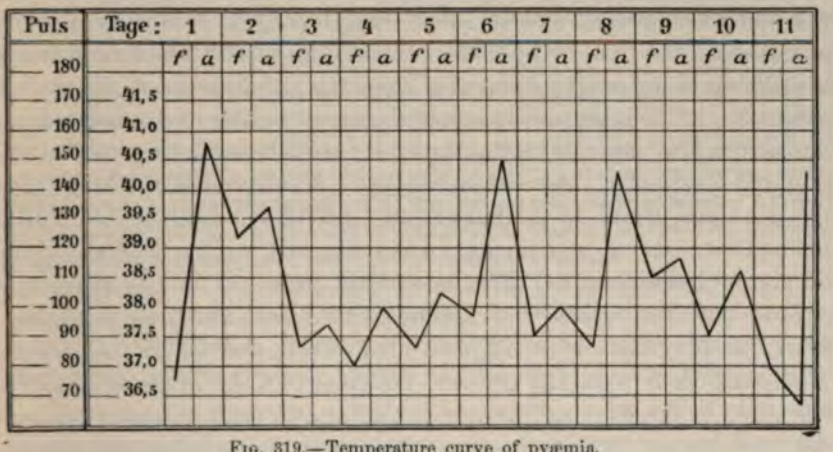


Fig. 319.—Temperature curve of pyæmia.

there is a sudden fall to a normal or subnormal point, and the temperature remains down for a variable length of time (Fig. 319).

Pyæmia is usually ushered in by a rigour, and in its subsequent course chills are of more or less frequent occurrence, the temperature rising with greater or less rapidity after each chill to 40° C. (104° F.) or higher, and just as rapidly again dropping to the normal. The length of time that each chill lasts varies very much. If the temperature rises gradually there will be no chills.

The intermissions may be repeated every twenty-four hours or every other day, or less frequently. After several days have elapsed without any fever it may be thought that the pyæmia has terminated favourably, when suddenly there will be a fresh chill followed by high fever, and then it will be known that the disease is still active. This peculiarly irregular course of the pyæmic fever is due to the fact that from time to time micrococci and the products of their metabolism

escape from some particular focus or collection of them into the general circulation. When their metabolic products have again been excreted from the blood the fever ceases.

The condition of the pulse corresponds to the course of the fever, but König is right in stating that the pulse of a pyæmic patient still remains rapid during the time when there is no fever, and never entirely falls to the normal rate. The general condition of the patient varies with the amount of the fever. The appetite is usually very poor; occasionally there is nausea or vomiting, and in the later stages there is apt to be a profuse diarrhœa. The urine ordinarily contains albumen and casts. Jaundice is common, and is sometimes, as in septicæmia, hæmatogenous, in consequence of the disintegration of the red blood-corpuscles; and in other cases it may be caused by pyæmic abscesses of the liver or by catarrhal swelling of the intestinal mucous membrane in the neighbourhood of the ductus choledochus. The other symptoms of pyæmia are, in general, caused by the metastatic inflammations in the internal organs, and vary greatly according to the extent and location of these inflammations. Metastases in the lungs give rise to hæmoptysis, to circumscribed catarrhal processes, to lobular pneumonia, extensive pulmonary abscesses, and to the different kinds of pleural inflammation. The metastatic processes in the abdominal organs, the liver, spleen, and kidneys, often give rise to so few symptoms that they cannot be diagnosticated during the life of the patient. Abscesses occur with the greatest frequency in the lungs and spleen, less often in the liver and kidneys. Metastatic joint inflammations are not uncommon. A large amount of albumen in the urine, with epithelium, casts, and an admixture of blood, indicate an acute metastatic nephritis.

If metastatic suppuration develops in the brain there will be corresponding symptoms of paralysis. Metastatic meningitis will present the picture of diffuse suppurative encephalitis.

The abscesses which may occur in the superficial organs, the lymph glands, parotid, joints, muscles, and subcutaneous cellular tissue, etc., are easily recognisable; they often cause no pain, and are accompanied with little inflammatory reaction, which is also the case with abscesses in the medulla of the bones. As in septicæmia, there is, in consequence of the disturbance of nutrition in the walls of the vessels, a tendency to capillary hæmorrhages; or, in consequence of the suppurative breaking down of a thrombus and the adjoining wall of the vessel, which may be situated within a focus of suppuration, hæmorrhages from the larger arteries and veins may take place, which will endanger the life of the patient. The eruptions on the skin are to be explained either as bac-

erial metastases in the skin or as angioneuroses due to the action of the bacterial toxines (R. Meyer). If the pyæmia starts from a granulating wound, it is sometimes noticed that the latter begins to suppurate less freely than before, the granulations become pale and flabby, and not infrequently break down or undergo diphtheritic changes.

The duration of a pyæmia is very uncertain. Generally it runs an acute course (eight to ten to twelve days), often a subacute (three to four weeks), less frequently a chronic course (two to three to five months). As in septicæmia, so also in pyæmia there are cases which apparently recover and then suddenly, after the lapse of months or a year or more, there occurs a fresh acute general infection starting from the old encapsulated pyæmic focus, to which the patient may succumb. The prognosis of pyæmia depends in general upon whether the local infection can be promptly overcome or not.

Prognosis of Pyæmia.—Acute pyæmia is usually fatal, and yet there are recorded cases of recovery in spite of internal metastases in the lungs, spleen, etc. The more frequently the chills are repeated, the more rapidly the strength fails, and the earlier the symptoms occur pointing to internal metastases, so much the more rapidly will the disease terminate in death. Chronic pyæmia finally kills the patient by exhaustion, unless the focus of infection that is present is subjected to proper surgical treatment.

Diagnosis.—In the diagnosis of pyæmia the irregular course of the fever, with intercurrent chills and the occurrence of metastases, are almost pathognomonic. Occasionally pyæmia is combined with septicæmia or with erysipelas, and then its course is masked by the other infectious-wound disease.

Treatment of Pyæmia.—Pyæmia is treated in essentially the same way as septicæmia. As in septicæmia, the local treatment of the source of infection is exceedingly important, and should be as energetic as possible—that is, every pyæmic collection of pus should be done away with at the earliest possible moment. All metastatic abscesses accessible to surgical treatment should be opened on antiseptic principles and disinfected. But the treatment of fully developed pyæmia, as of septicæmia, is, for the most part, of no avail. It must, however, never be forgotten that we have a certain means of preventing both diseases by practising thorough antisepsis in the treatment of every wound. If the patient is long confined to bed, disturbances of the circulation, as a result of cardiac and respiratory weakness, are very apt to occur in the skin, followed by necrosis of the latter—in other words, bedsores or decubitus may appear, especially in those regions where the skin is closely superimposed upon the bones, as over the sacrum, the trochanters, scapulæ, and elbows. To avoid this complication, these areas of skin should be carefully protected from pressure by the use of air- or water-cushions, and they should be kept scrupulously clean by washing them

with alcohol, etc. The treatment of bedsores after they have developed will be discussed under the subject of ulcers (see § 93, Diseases of the Skin).

§ 76. **Infection by Cadaveric Poison.**—All individuals who have much to do with cadavers or dead animal matter, and so all physicians, anatomists, butchers, cooks, etc., are liable, on the reception often of trifling injuries, to suffer from infectious inflammations of various sorts, which very often lead to fatal general poisoning. The so-called cadaveric poison is more or less identical with the poison of decomposition. But the bodies of all animals which have died from a specific infectious-wound disease, such as erysipelas, pyæmia, anthrax, rabies, etc., still harbour the specific bacteria which caused this infectious disease, and these bacteria remain capable of exciting the same disease for the first twenty-four hours after death. When decomposition of the dead body sets in, the specific bacteria of pyæmia, erysipelas, anthrax, etc., perish, succumbing in the struggle for existence with the bacteria of decomposition. Consequently there may be various poisonous substances in the cadaver, notably the excitants and products of decomposition, and also, in the period immediately following death, the excitants of specific diseases. Therefore it can be understood why the infections of wounds from dead bodies have very different clinical results, and that septicæmia and pyæmia, as well as specific diseases like anthrax and tuberculosis, are alike transmissible from cadavers. Infection with cadaver poison usually takes place through a small incised or punctured wound, an abrasion of the skin from a splinter or sharp edge of bone, etc., and frequently the injury is so trifling as not to bleed, and may be entirely overlooked. As a general thing it is better when the wound bleeds, as then any bacteria which may have lodged in it are apt to be swept out by the flow of blood.

In the first place, there are wound infections which run a very acute course, particularly those in which the infection is from a septic cadaver. This may also occur in surgeons after they have operated upon a collection of foul pus in a living patient. The septic-wound infection may, in the worst cases, exhibit the following peculiarities: At the outset there is a small injury, which generally causes only a slight amount of pain, and then very soon there occur headache, nausea, general lassitude, a severe chill, and a rapid rise of temperature. In the worst cases, which are, however, not common, death may follow within two to three days, preceded by delirium and stupor, and yet the point where infection took place will not show any noticeable local inflammation. These are the cases of acute septicæmia which have been described in § 74. It is still a question whether these severe forms of

septicæmia can be caused by infection from a non-septic cadaver—i. e., by infection with the usual cadaveric poison.

Comparatively often, after infection from a dead body, a circumscribed inflammation will begin in the neighbourhood of the wound, terminating in suppuration, and having a tendency to gangrene, with secondary lymphangitis, phlebitis, and purulent lymphadenitis, for example, in the epitrochlear and axillary glands. Sometimes the course of the disease is very protracted, and there are cases which act like chronic pyæmia. These latter are apt to occur after infection from the dead body of a patient who has died of pyæmia.

Cadaver Tuberculosis (*Verruca necrogenica*).—The so-called anatomical tubercle is a peculiar chronic form of infection from dead bodies, and is the name given to wart-like, moist, often ulcerating growths, which are particularly liable to occur upon the backs of the hands or the knuckles of those who habitually handle cadavers, such as anatomists, demonstrators, etc. The anatomical tubercle usually remains local, though there may be attacks of acute lymphangitis and lymphadenitis, with possibly the formation of abscesses. Baumgarten, Riehl, and others have demonstrated that the anatomical tubercle is not the result exclusively of ordinary cadaver poisoning, as these investigators have found tubercle bacilli in the tubercles. Consequently it is an undoubted fact that some anatomical tubercles, at least, are forms of local tuberculosis.

There occasionally result from cadaver infection small abscesses and pustules without any injury of the skin having occurred; under these conditions the poisonous substances are lodged in the normal cutaneous pores, especially the sebaceous glands.

Zoönotic Erysipeloid.—In this class of cases belongs the so-called *zoönotic finger-erysipeloid*—chronic erysipelas or erythema migrans—which has been described on page 357.

Mention has been made of the fact that very dangerous, specific, infectious-wound diseases can be transmitted to man from the dead bodies of human beings and animals, particularly within the first twenty-four hours following death. This matter will be discussed again when we come to the subjects of anthrax, syphilis, etc.

Prophylaxis and Treatment of Cadaver Infection.—From these facts it follows that every one having much to do with dead human or animal bodies should use the greatest precautions. To *prevent* cadaveric infection, the hands should be thoroughly disinfected in the way described on pages 10 and 12. By this means the so-called anatomical tubercle can be avoided with certainty, and after it has broken out it can be caused to gradually disappear by the use of bichloride

washes and dressings. If post-mortem examinations have to be undertaken upon bodies infected with pyæmia, septicæmia, anthrax, etc., or in case of small scratches or wounds of the hand, it is an excellent plan to cover the hands with carbolised vaseline, rubber gloves, etc.

If an injury is sustained during the autopsy the blood should be pressed out of the wound, or the latter should be sucked and then thoroughly disinfected, no matter how trifling it may be, with a one-fifth-per-cent. solution of bichloride of mercury, or a five-per-cent. solution of carbolic acid. These remedies are better than the application of caustic acids which form an eschar, such as nitric acid, which was at one time very frequently used. After many years' experience as an anatomist, Louge advises that before undertaking an autopsy all cracks or scratches on the hands should be painted with tincture of iodine; and he has also adopted the same treatment for any wound received during the course of the autopsy, after it has stopped bleeding. If local inflammation or systemic infection should occur, either condition should be treated upon the principles which have been laid down in a previous chapter. Long and deep incisions should always be made at an early stage at the point of infection, and these should be followed by the continuous application of solutions of bichloride of mercury varying in strength from 1 to 500 to 1 to 1,000 of water, acetate of aluminium 1 to 2 per cent., etc. Morphine should be exhibited hypodermically to alleviate pain.

FIG. 320.—Blood from a mouse infected with anthrax; red corpuscles and anthrax bacilli. The latter are stained with methylene blue. × 800.

FIG. 321.—Anthrax threads from the blood of a mouse. Taken from a bouillon culture ten hours old at 24° C. At *a* the threads are seen distinctly to be made up of separate bacilli. × 700.

§ 77. **Splenic Fever or Anthrax.**—Anthrax is an acute infectious disease caused by a specific bacillus, and is one of the most widely distributed and fatal of diseases, particularly among cattle, and it is not infrequently communicated from them to man. The name *splenic*

derived from the fact that animals afflicted with this disease ery much enlarged spleen.

gy of Anthrax.—Accurate knowledge had been obtained about the anthrax before anything was known about the etiology of the terial infectious diseases. In 1849 Pollender and vorking entirely independently of each other, dis- n the blood of cattle dying of anthrax, fine rod- ructures, and afterwards recognised their vegetable Davaine was the first to prove that anthrax could cited in healthy animals by inoculating the latter d which contained no bacteria, but that it could be by inoculations with blood in which the bacilli ent (1863). These experiments were frequently re- ıd always with the same results, Pasteur, in par- ing blood which had been freed from formed ele- filtering it through porcelain. Robert Koch has us with the most important facts concerning an- its bacilli.

Fig. 322.—Stab culture of anthrax in gelatine. Eight days old.

ax Bacillus.—The anthrax bacillus (*bacillus an-* s a transparent rod, incapable of motion, possesses ends, and is 3 to 10 μ long and 1.0 to 1.2 μ broad . It is found in the blood of animals suffering rax either singly, each bacillus by itself, or in fila- ıde up of two to six to ten little rods connected Fig. 321). The line of separation between the indi- cilli is often plainly distinguishable, causing the filaments to assume a characteristic appearance. lus is incapable of motion and is aërobic—that is, the presence of oxygen to grow, the most favour- erature being that obtained in a culture oven, and pment takes place below 15° C. or above 45° C. ine is rapidly liquefied. Gelatine puncture cul- ılly present the appearance illustrated in Fig. 322 fine processes, thorns, or needles radiate from the line in which the was made. On gelatine plates colonies develop with a notched, order or a cone-shaped coil, from which filamentous extensions ıt in all directions. On potatoes the bacillus forms a dry, white . 323); on agar there develops a greyish, slightly glistening cover- ıll artificial nutritive media long filaments are formed made up of ıdreds, or even thousands, of separate bacilli. When the nutrition ne exhausted from the culture medium, provided oxygen is present emperature remains between 18° and 40° C., the bacilli develop hich have the shape of small drops with a strongly refractive The best spores form in temperatures between 20° to 25° C. At the urable temperature the spores are formed in twenty-four hours; it takes seventy to seventy-five hours. After the spores have ned the bacillus breaks up, and the spores are liberated and can ey lodge upon a proper nutritive medium, each grow into a bacil-

lus. The powers of resistance possessed by anthrax spores vary v particular noxious influence to which they may be subjected, a five-p solution of carbolic acid, for instance, killing them in two to thirty days, while steam at a temperature of 100° C. will destroy their vitality in three to ten to twelve minutes.

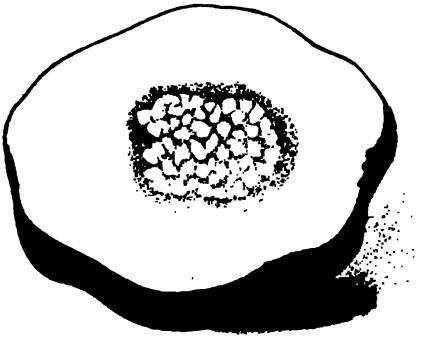


FIG. 323.—Pure culture of anthrax bacilli upon a boiled potato.

FIG. 324.—Anthrax threads containing × 800.

If bichromate of potassium, in the proportion of 1 to 2,000–5,000, is a a nutritive medium containing anthrax, such as bouillon, the bacilli v their power of forming spores. The same result can be obtained by ing bouillon cultures containing carbolic acid (in the proportion of 10,000) for eight days to a temperature ranging between 30° and Anthrax bacilli thus rendered incapable of forming spores lose none virulence when used for inoculating purposes; nevertheless, the speci regains its lost power of developing spores. There is some difference l the shape and the appearance of the cul the ordinary anthrax bacilli and those r incapable of spore formation. This f peculiar significance, showing, as it do the bacteria exhibit marked differences ing upon the medium in which they and that they cannot be distinguished fr another without taking other things count besides their shape and the appear the culture. When they have exhaus nutritive principles from any medium i they are growing the bacilli die or tak volution forms. The anthrax bacilli de spores in the living animal body and undecomposed cadaver, as this process w take place when the access of oxygen is unhindered.

FIG. 325.—Anthrax spores from a culture twenty-four hours old. The spores, which are stained red with fuchsin, are partly free and partly within the bacilli stained with methylene blue. (See also Fig. 264.)

The best way to study the development of the bacilli under th scope is to place a drop of the ordinary culture bouillon containing th in the concavity of a slide.

Artificial Attenuation of the Virulence of Anthrax Bacilli.—The virulence of anthrax bacilli can be weakened or attenuated in various ways, such as subjecting them to a high or low temperature, or making the culture grow for a long time—twenty-four days or so—at a temperature of 42° to 43° C. By treating them in some such manner it is possible to render anthrax bacilli entirely innocuous (Koch, Löffler, etc.).

By cultivating them in bouillon made of fresh blood from guinea-pigs the lost virulence can be restored (Chauveau). The attenuated bacillus forms metabolic products, which differ from those of virulent anthrax, the latter producing on artificial nutritive media large amounts of acid, while the former is more prone to form alkaline substances (Behring).

The virulence of anthrax bacteria can be weakened by various antagonistic bacteria, such as the cocci of erysipelas, the *Bacillus pyocyaneus*, Friedländer's pneumococcus, the *Micrococcus prodigiosus*, the *Bacillus putidus* and *albus*, etc. Baumgarten and others found that when the *Staphylococcus pyogenes aureus* comes in contact with anthrax bacilli in the bodies of mice and guinea-pigs, the former increases very much in virulence and causes a fatal septicæmia, while at the same time the development of the anthrax bacilli is completely arrested. Also, sterilised cultures of these antagonistic bacteria exert, according to Buchner, a restraint upon the development of anthrax bacilli, whence it follows that the chemical substances derived from the above-mentioned bacteria are the active restraining agents. These facts concerning the attenuation of anthrax bacilli have been made use of for bringing about artificial immunity against virulent anthrax bacilli. Pasteur tried to make cattle and sheep susceptible to anthrax by inoculating them with bacilli which had been attenuated by cultivation at a temperature of 42° to 43° C. The principle is the same as in vaccination with cow-pox for protection from variola; but Pasteur's inoculation with attenuated anthrax does not always seem to give immunity from infection occurring in the ordinary way through the intestine. Hankin, in Koch's institute, isolated a poisonous albumose from anthrax cultures, which produced in mice and rabbits immunity from anthrax when exhibited in very small doses. Emmerich, Di Mattei, and others inoculated animals (rabbits) with the erysipelas coccus, and they became afterwards unsusceptible to anthrax. Emmerich has prepared a germ-free serum from sheep infected with erysipelas-streptococci for the treatment of anthrax in man. The discovery made by Wooldridge is exceedingly interesting. He found that injections of a solution of fibrinogen which had been used for the cultivation of anthrax made animals immune from this disease, and that the same result could also be obtained by using fibrinogen which had been subjected to a slight chemical change without making use of anthrax bacilli. Charrin and Bouchard have checked anthrax at its inception in animals by inoculating them with the *Bacillus pyocyaneus*, and have cured the disease.

Most authors are of the opinion that anthrax bacilli lose some of their virulence after having passed through the body of an animal which is not susceptible to them. On the other hand, Malm was able to show that their virulence is increased.

Occurrence and Origin of Anthrax.—Anthrax is widely distributed in many countries, such as Russia, Siberia, Hungary, India, Persia, and in certain

districts of France and Germany, and yearly works destruction in herds of cattle, particularly during the hot summer months, while in winter it ceases its ravages. In England and North America anthrax is not so common. The anthrax bacillus has not yet been proved to exist outside of the animal body. In grazing animals (sheep, cattle, horses) the bacillus is most commonly taken into the system through the intestine, less often by cutaneous inoculation. Mice, guinea-pigs, and rabbits are easily infected by inhaling the spores, and are not readily infected through the intestine. In man, anthrax is communicated particularly by infection of small cutaneous wounds (malignant pustule), less often through the lungs and intestine. The anthrax bacilli multiply very rapidly in the animal body, and are found not only at the point of infection—the malignant pustule, for example (Fig. 326)—but also in the blood-vessels, where they exist in vast numbers. They are also present, immediately after the infection takes place, in the lymph and the chyle when the infection occurs through the intestine. In the malignant pustule the anthrax bacilli will be frequently found enclosed within cells, a fact which cannot be considered as supporting Metschnikoff's theory of phagocytosis (see pages 276, 277), as the bacilli were probably dead before they were taken up by the cells. The infected organism usually succumbs very soon in consequence of the rapid multiplication of the bacilli and the poisonous products of their metabolism. The toxic products (albumoses and bases) of the anthrax bacilli have been studied by Hankin, Lando Landi, and others.

Fig. 326.—Anthrax bacilli from a malignant pustule of the skin. The bacilli are stained with gentian violet, and the tissues with Bismarck brown. × 300.

Natural Immunity of certain Animals from Anthrax.—Dogs, pigs, and the majority of birds, are immune from anthrax; also rats, for the most part, and frogs under ordinary conditions. But if a frog, in whose lymph sac are placed anthrax spores, is put in an incubation apparatus, he will quickly die of anthrax. According to Rohrschneider, 28° C. is the lowest limit of temperature at which anthrax bacilli will develop within a frog's body. According to Crookshank, pigs may acquire anthrax. Ssawtschenko stated that after the spinal cord is divided in doves they are no longer immune from anthrax. In general, the immunity which various animals possess towards anthrax does not appear to be complete, as the bacilli can gradually become accustomed to develop in media which are unsuitable for them.

Fig. 327.—Anthrax bacilli in the capillaries of an intestinal villus (rabbit), stained with methylene violet and then treated with potassium carbonate. × 800.

It has been proved by Birch-Hirschfeld and others that anthrax bacilli

can be transmitted from the mother to the fœtus *in utero*. The bacilli, as it were, grow into the fœtal placenta, aided by changes in the walls of the vessels, in the tissues surrounding the vessels, and in the epithelium of the villi. The healthy placenta does not normally permit the passage into and through it of micro-organisms or other formed elements, and the filter only becomes pervious when affected by pathogenic bacteria which have gained access to the placenta.

Staining of Anthrax Bacilli.—The anthrax bacillus can be rapidly stained by aqueous solutions of the aniline dyes, and also by Gram's method. The spores are best stained at a high temperature by means of Ehrlich's aniline-water-fuchsin solution or Ziehl's solution containing carbolic acid. Instead of Ehrlich's fuchsin solution, a correspondingly made solution of gentian violet can be employed for staining the spores. After decoloration of the substance of the bacilli the spores are stained with Bismarck brown.

The Course of Anthrax in Animals.—Anthrax in domestic animals may take one of three courses: 1, The apoplectiform anthrax (anthrax acutissimus), which lasts from a few minutes to several hours; 2, the acute anthrax (anthrax acutus), lasting from a few hours to several days; and, 3, the subacute form of anthrax (anthrax subacutus), of longer duration. There is no period of incubation, or it may occupy three to five days. In the more common apoplectiform variety of anthrax (cattle, sheep) the animals which previously had apparently been in perfect health fall down as though struck with a blow, and die often in a few minutes with convulsions, cyanosis, and dyspnœa. According to Bollinger, acute anthrax in cattle and horses begins with loss of appetite and a chill, followed by a remittent or intermittent high fever (41° C.—105.8° F.—and higher); there are almost always spasms, particularly clonic spasms of the extremities. These symptoms come on in the form of paroxysms. The subacute form of anthrax, the anthrax carbuncle, is characterised by carbunculous and erysipelatous swelling occurring in different places in the skin, particularly in the region of the hind feet, while there is only a slight constitutional disturbance. The carbuncle begins to be absorbed frequently after the lapse of a few days, and an eschar and ulceration develop only exceptionally. In about sixty to seventy per cent. of the subacute cases (in cattle and horses, for example) death follows with dyspnœa and convulsions.

Anthrax in Man.—Anthrax occurs in man mainly by transmission of the anthrax bacilli or their spores from a diseased animal, and hence those persons are particularly liable to the disease who in their occupation come in contact with infected animals or parts of animals. Such persons are shepherds, farmers, butchers, veterinary surgeons, workers in leather (furriers, and those who handle skins), and people who are employed in the preparation of horse-hair, wool, and paper.

The so-called *rag-sorters' disease*, which runs a rapidly fatal course, presenting the appearance of pneumonia with typhoid or septic symptoms, and attacks people who sort and tear rags in the manufacture of paper, is occasionally primary anthrax of the lungs caused by inhaling

anthrax spores. Kraunhals states that the disease is also caused by the bacillus of malignant œdema. There is a great variety of micro-organisms in rags. O. Roth describes three kinds of pathogenic bacilli: Bacillus I is like the *Bacterium coli*, Bacillus II like the *Proteus hominis*, and Bacillus III like Hauser's *Proteus vulgaris* (see page 373).

Enderlen's experiments in the Pathological Institute at Munich show that breathing in the spores of anthrax is much more dangerous than their ingestion in food. All "inhalation animals" perished of anthrax, while of the animals infected through food some remained alive. Anthrax is also caused in man by eating the flesh, milk, or butter obtained from animals affected with this disease. It may also be transmitted by insects (flies) which come in contact with animals having anthrax, and the poison may be communicated from man to man—for example, at an autopsy. The disease starts either by inoculation of the bacilli or of their spores into the skin (it may be a very small interruption of continuity), or by inhalation of the poison, or by its introduction with the food into the alimentary canal. The cases of so-called intestinal mycosis recorded by E. Wagner and others are really cases of true anthrax disease. In general man is only slightly disposed towards anthrax. Marchand observed anthrax in a pregnant woman with fatal infection of the child. Lingard, experimenting with pregnant rabbits, caused an infection of the fœtus, and found that in some cases the fœtus alone became diseased, in others the mother also. Sections through the placenta plainly showed the passage of the anthrax bacilli from the fœtal to the maternal blood-vessels. Birch-Hirschfeld's recent observations, which were mentioned before, are very interesting, proving, as they do, the transmission of the anthrax bacilli from the maternal into the fœtal circulation. If an abundant development of anthrax bacilli takes place in the placenta, the bacteria actually grow into and through the fœtal portion of the placenta in a manner similar to that in which, after inhalation of anthrax spores, the bacilli enter the pulmonary vessels, as was demonstrated by Buchner's experiments.

The course which anthrax takes in man varies according to whether the infection takes place externally or internally. When infection occurs through the skin there is an incubation period of three to six days, and then at the point of entrance there develops a burning or itching red nodule with a reddish or bluish bleb, which soon breaks and dries up, forming a scab. The skin in the neighbourhood of the scab then usually becomes swollen, and sometimes more blebs form. The primary nodule at the point of infection varies from the size of a pea to that of a nut. Ordinarily the induration and œdematous swelling extend very rapidly in all directions from the primary nodule, an

the adjoining lymphatic glands become enlarged. After the local symptoms have continued some forty-eight to sixty hours the constitutional manifestations of the disease begin (high fever, great weakness, delirium, diarrhœa, severe vague pains, etc.). If there is a fatal termination, death occurs very often with symptoms of collapse, generally after the disease has lasted five to eight days. If there is a favourable termination the scab is sometimes cast off by a process of suppuration. In other cases there is observed a diffuse, erysipelatous form of carbuncle (Virchow, Bollinger)—for example, after infection by a fly-bite, and also when the infection has taken place internally. The course of anthrax when the infection has taken place from the intestine is characterised by the suddenness of the onset and its rapid progress, with vomiting, diarrhœa, cyanosis, and subsequent collapse. When the infection takes place through the lungs, as in the above-mentioned rag-sorters' disease, there is observed a pneumonia, with typhoid or septic symptoms, and for the most part a rapidly fatal course. The autopsy in man reveals essentially the same changes as in animals. There are immense numbers of anthrax bacilli in the blood-vessels, and particularly in the capillaries (Fig. 327).

The Diagnosis of Anthrax, when infection has occurred through the skin, is made chiefly from the characteristic appearance of the malignant pustule, and from the patient's statements concerning his occupation, the origin of the pustule, etc. If necessary, the diagnosis can be cleared up by microscopical examination of the carbuncle. For making the diagnosis when the infection takes place from within, we must refer the reader to the text-books on internal medicine.

Prognosis.—The prognosis of anthrax in man, when infection takes place externally, depends mainly upon whether energetic surgical treatment is undertaken early enough. Lengyel and Koranyi, by adopting suitable local treatment, lost only thirteen out of one hundred and forty-two cases of anthrax. Patients with anthrax resulting from internal infection (intestinal, pulmonary) very rarely recover.

The Treatment of Anthrax.—In the treatment of anthrax in man the fact that the disease remains local a longer time than in animals is of the greatest importance. If the patient comes under observation early enough, it is our duty to destroy the point of infection as rapidly and thoroughly as possible—for instance, by extirpation, by making an eschar with the Paquelin, by cauterisation with nitric acid, etc. According to Koch, bichloride of mercury is the most effective poison for anthrax bacilli, being capable of killing them when used as dilute as 1 part to 300,000 of water. Consequently it is an excellent plan to use in and around the point of infection injections of one tenth per cent. bichloride, or two to five per cent. carbolic acid (Raimbert and

others), or dilute tincture of iodine (one to two of water, Davaine). Russian surgeons in particular have obtained very good results from the free use of carbolic acid both subcutaneously and internally. As much as half a gramme of carbolic is given internally during the day, and a considerable quantity is injected into the pustule. In suitable cases, which come under treatment at an early stage, with anthrax infection located in an extremity, the latter can be tied off by an elastic tourniquet (Nissen). The diet should be strengthening and alcohol is given in large doses. The future must decide whether it is possible in man, as in animals, to prevent anthrax or to cure it, by the inoculation of other kinds of bacteria (see page 391). Emmerich has prepared a germ-free serum from the blood of sheep infected with erysipelas streptococci and used it in human anthrax. The reports thus far published in literature are too few to allow of a correct judgment of the value of this curative serum.

Symptomatic Anthrax.—Symptomatic anthrax (*charbon symptomatique* of the French) is a disease similar to anthrax, affecting cattle, which occurs endemically and mostly during the warm months of the year in many regions, notably the Bavarian Alps, Baden, Schleswig-Holstein, etc., and has long been confused with anthrax. Symptomatic anthrax has not hitherto been known to occur in man. The disease has been studied by Bollinger, Kitasato, and others. It is characterised by the formation of irregularly outlined, emphysematous, crackling swellings of the skin and muscular tissue, particularly on the thigh, and by a peculiar reddish-black discoloration of the diseased muscles. In the bloody serous fluid at the focus of the disease there is found a characteristic bacillus, which Kitasato was the first to obtain in pure cultures upon a solid nutritive medium. By inoculating animals with this bacillus Kitasato excited typical symptomatic anthrax.

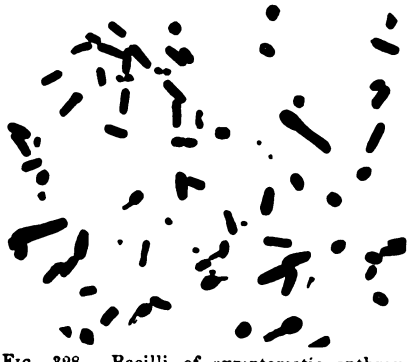


Fig. 328.—Bacilli of symptomatic anthrax. Spore-bearing rods from a culture in agar. Cover-glass preparation, stained with fuchsin. × 1000 (Fränkel and Pfeiffer).

The *bacillus* of symptomatic anthrax (Fig. 328) is a rather large, slim, actively moving rod with plainly rounded ends, generally occurring singly, occasionally in pairs, but never in long filaments. It is strictly anaërobic, and when brought in contact with the oxygen of the air soon perishes. It grows at ordinary temperatures above 18° C., but best in the incubator. The spores form large, strongly refracting bodies, rather long, and are placed eccentrically at the end of the rod (Fig. 328). When the spores become free the rest of the bacillus speedily dies. The spores, which have great powers of resistance, do not form in living animals, but do so in dead bodies and in

cultures. It is worth noting that the older cells, or those which vn in media unsuitable for them, have a tendency to develop invo- rms, which sometimes take the shape of large, ›indle-like segments enlarged in the centre, and a granular cloudiness and an irregular contour. latine to which has been added grape sugar or er reducing substance there develop within a few rical masses, which rapidly liquefy the nutritive Fig. 329). In stab cultures, made in a large amount ıe, a cloudy, grey liquefaction takes place in the ly placed parts, with the evolution of gas having eristic acid odour. Agar, at the temperature of ıtor, becomes filled with bubbles of gas even after of twenty-four hours. In bouillon, white flakes the bottom of the vessel, accompanied by the for- gas. When cultivated at a temperature of 42° to virulence of the bacilli is rapidly caused to disap- e spores, particularly when subjected to high tem- lose their virulence; but if placed in a twenty-per- ion of lactic acid and then injected into susceptible hey can be made to regain their virulence, and in an increased amount. By inoculating suscep- ıals with pure cultures the animals quickly die of ıtic anthrax with the above-described symptoms. ural conditions the disease occurs, in the majority from infection of small wounds, particularly of ıities, less often from infection through the lungs ne. The poison is conveyed especially by the the bacilli quickly perish when exposed to the air. ible in various ways to obtain immunity from ıtic anthrax, and for this purpose "vaccination" ble "vaccine" is very worthy of recommendation. acilli of symptomatic anthrax are stained in the way. The little rods, when subjected to Gram's ›se their stain again. The spores cannot be stained ıs solutions of the aniline dyes, but readily take e stain.

Fig. 329.—Bacilli of symptomatic anthrax. Pure culture four days old, after scattering the inoculating material about in grape-sugar gelatine; unstained; natural size (Fränkel and Pfeiffer).

Glanders or Farcy (*Malleus*).—Glanders is an infectious dis- to bacilli, primarily occurring, by preference, in horses and l is transmissible to man and all domestic animals, with the ception of cattle. The disease is characterised by the pres- peculiar small and large nodules, particularly in the mucous ıe of the respiratory tract, and in the skin, with secondary c nodules in the internal organs (spleen, liver, kidneys, testicle, c.).

r and Schütz demonstrated four years ago the presence of the istic bacilli in the glanders nodules and made pure cultures

of the bacilli upon artificial nutritive media, and produced typic glanders by inoculating various animals with these cultures. Israe Kitt, and Weichselbaum have also found the same bacilli in glander and have successfully inoculated other animals with them, so that ther can be no doubt that these bacilli are the cause of the disease.

Glanders Bacilli.—The *glanders bacilli* (Fig. 330) are slim rods simila to tubercle bacilli, but more regular as regards their size, and somewhat broade than the latter. They possess no inherent power of motion. The bacilli, lik most of the pathogenic bacteria, are facultative anaërobic, and can be culti vated in the necessary nutritive medium at temperatures ranging between 25 and 40° C., and in the presence of oxygen. Upon potatoes there forms, at th ordinary incubator temperature, in the course of about two days, a yellowisl honey-like layer, which afterwards gradually becomes darker, varying fro brownish to dark red. Upon agar the colonies form a whitish shining laye and upon blood serum, which does not become liquefied, a clear, transparer covering in the form of drops, which later coalesce. The formation of spor by the glanders bacillus has not yet been demonstrated, but is considere probable by Löffler, Baumgarten, and Rosenthal. Prolonged cultivatio upon artificial nutritive media causes the glanders bacillus soon to lose i virulence. By inoculation of pure cultures of glanders bacilli upon susce tible animals (horse, ass, goat, cat, field mouse, house mouse, guinea-pig) th typical form of glanders is produced, the glanders bacilli being mainly foun

FIG. 330.—Bacillus of glanders. Pure cultures upon glycerine-agar; teased specimen stained with carbolic fuchsin. × 100 (Fränkel and Pfeiffer).

FIG. 331.—Glanders bacilli. Smear of p from a guinea-pig that had died of gla ders. The four crossed bacilli within th group of leucocytes are particularly cha acteristic. × 650 (Heim).

in the centre of the specific glanders nodules. Less susceptibility to glande is evinced by hogs, sheep, rabbits, and dogs, with the exception of young dog which according to Flügge are very susceptible to the disease. Cattle, hous mice, white mice, and rats, are entirely unsusceptible. Field mice die in fro three to four days after an artificial subcutaneous infection with glander guinea-pigs only in the course of several weeks. Leo states that white mi lose their natural immunity and become susceptible to glanders if they a made artificially diabetic by feeding them with phlorizin. The richer t blood of a particular animal in oxygen, the less able is the glanders pois

to develop (Sanarelli). By continuous transmission of glanders bacilli from one animal to another it is possible to cause a remarkable increase in their virulence (Gamaléia). Babes obtained the chemical product of metabolism of the glanders bacilli through precipitation from filtered cultures in horse-flesh bouillon, by equal parts of ether and alcohol. This substance, called "mallein" or "morvin," does not cause ocal lesions, but produces symptoms of ntoxication (fever, convulsions, nephritis, narasmus, death). Babes cured a horse hat had glanders with injections of mor-in, and he also used protective inocula-ions with success.

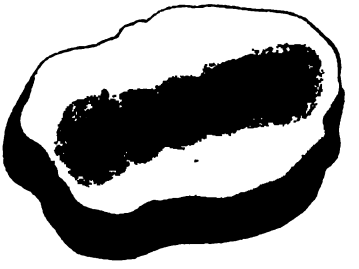


Fig. 332.—Potato culture of the glanders bacillus at 37° C.; four days old.

The bacilli exist in the specific new issue formations partly singly and partly n irregular collections or bunches of sev-ral parallel rods. The glanders prepara-ions, or rather the glanders bacilli, are tained with concentrated alkaline solu-ions of methyl blue. They are then treated with greatly diluted acetic acid, rashed in alcohol, and embedded in oil of cedar. Glanders bacilli cannot e stained by Gram's method. Among the recent methods of staining the ollowing are particularly good: Weigert's aniline method, Unna's dry nethod, and the method of R. Kühne (sections placed for six to eight hours n carbolised methylene blue, then decolorised in acetic acid, and again in listilled water, dried upon the slide, clarified with xylol and embedded in Canada balsam).

Noniewicz recommends the following combination of Löffler's and Unna's taining methods: 1. Place the section taken from alcohol in Löffler's solu-ion of methylene blue for from two to five minutes. 2. Wash in distilled water, and stain for from two to five seconds in seventy-five parts of one-half-per-cent. acetic acid and twenty-five parts of one-half-per-cent. tropæolin. 3. Wash in distilled water. 4. Dry upon the slide, apply a drop of xylol, and examine in xylol and Canada balsam.

According to Noniewicz, glanders is caused partly by bacilli and partly by a coccus form. The round bodies are found particularly in subacute and chronic glanders.

Glanders infection, under natural conditions, generally occurs through ome small injury of the skin or mucous membranes, and by inhalation. Babes has produced glanders in guinea-pigs by rubbing very virulent glan-lers bacilli into the sound skin; whence it follows that glanders bacilli are lso able to penetrate into the hair follicles of the uninjured skin.

Glanders in Animals.—Glanders occurs in horses and other animals in e form of small or large nodules, or as a diffuse infiltration. The glanders odules appear especially upon the mucous membrane of the respiratory act and upon the skin. The nodules occurring in the mucous membrane the respiratory tract, especially that of the nose, the larynx, and trachea, ry between the size of a grain of sand and a pea. At the outset they have reyish-white or greyish-yellow colour, and appear singly or in groups l are surrounded by a red areola. From a suppurative breaking down,

often within a few days, there result proportionately large ulcers, which usually enlarge rapidly by necrosis of the surrounding parts, extending also deeply into the subjacent tissues. In the lungs the glanders nodules are similar to tubercular nodules, appearing partly as lobular foci of inflammation and partly as interstitial nodules. The pulmonary glanders nodules occur, according to Bollinger and others, partly from direct aspiration of the glanders poison and partly as a result of embolism. In addition to the circumscribed glanders nodules there are also found in the lungs diffuse infiltrations.

Upon the skin there occur, in the cutaneous form of glanders, small (miliary) or large nodules, accompanied by a rapid suppurative breaking down, and the formation of ulcers which quickly extend and also lead to inflammation of the lymphatic vessels and glands. Cutaneous glanders in rare cases may also occur, by an embolic process, secondarily to primary glanders of the respiratory mucous membrane. As was mentioned before, secondary glanders may also be found in the spleen and liver and in the bones, less often in the kidneys and testes, as a result of embolism.

The course of glanders may be acute or chronic, in the former terminating in death in six to twelve days; the latter, the more common form, may last for years.

Glanders in Man.—The transmission of glanders to man does not take place very frequently. Individuals—such as butchers, hostlers, cavalry soldiers, veterinary surgeons, etc.—who come in contact with animals, especially horses, which have glanders, are particularly apt to contract the disease. In man the disease takes the form of glanders of the conjunctiva, less often of the nasal mucous membrane, and particularly glanders of the skin, originating in some insignificant injury, especially about the face and on the hands. In man also, as in animals, glanders may run an acute or chronic course, and there may develop the above-described glanders nodules and ulcerations at the point of infection, and secondary nodules in the internal organs as a result of embolism. Acute glanders runs a course marked by severe typhoid, septic manifestations, and sometimes it may resemble acute articular rheumatism. The disease not infrequently begins with a general feeling of malaise, and pains in all the limbs, in the joints and in the back. In conjunction with a high fever there develop at the point of infection typical glanders nodes which break down and ulcerate. Upon the skin pustular erup-

Fig. 333.—Acute glanders eight days old in man. Well-developed ulcerations of the skin of the face (Birch-Hirschfeld).

tions appear, which change into phagedænic ulcers, having a dirty, lardaceous base. Birch-Hirschfeld saw pemphigus-like blebs upon the skin of the nose and cheeks, with rapid destruction of the greater part of the skin of the face (Fig. 333). In cutaneous glanders there are also not infrequently observed diffuse erysipelatous inflammations, and particularly lymphangitis and phlegmonous infiltrations of the subcutaneous cellular tissue, terminating in suppuration or ulcerative destructive processes. The secondary foci of glanders, particularly those in the internal organs, bear in acute glanders a close resemblance in every respect to pyæmic foci of pus, in chronic glanders to cheesy formations.

The above-described affection of the nose so characteristic of glanders in the horse, is not so frequently observed in man, and occasionally it first makes its appearance rather late in the disease. Acute glanders is accompanied by high fever, and runs a regularly fatal course within days or weeks, in consequence of the increasing systemic infection, with the formation of secondary nodes or abscesses in the internal organs as well as in the muscles and subcutaneous cellular tissue. Chronic glanders in man has hitherto been less accurately observed. König gives its average duration as four months. It runs a course essentially analogous to the above-described chronic glanders in the horse. Birch-Hirschfeld calls attention to the resemblance of chronic glanders to syphilitic and tubercular disease. According to König, the mortality of chronic glanders is about fifty per cent.

Diagnosis of Glanders.—The diagnosis of glanders in primary infection of the skin and nasal mucous membrane is usually not difficult, in consequence of the characteristic behaviour of the glanders nodes taken in conjunction with the occupation of the patient. Internal glanders of the larynx, trachea, and lungs may often be first recognised when secondary affections of the skin occur, or when the characteristic glanders bacilli are demonstrated in the sputum. The demonstration of the bacilli in every case is, of course, of the greatest diagnostic importance. A good method for quickly diagnosing glanders consists in mixing the suspected secretion with water and then injecting it intraperitoneally into male guinea-pigs. If it is really glanders, after the lapse of two to three days there occurs a swelling of the testicles which increases during the next few days. Suppuration occurs within the tunica vaginalis and spreads to the testicles; the pus contains glanders bacilli. Levy and Steinmetz recommend making the injection in the median line of the abdomen above the bladder, in order to prevent injury to the seminal vesicles, which in case of infection might give rise to *secondary* inflammation of the testicle. It is particularly important in glanders, both for the patient and those about him, to make an early diagnosis of the disease and to employ energetic treatment.

Treatment of Glanders.—The treatment of glanders can only be successful when the point of infection can be destroyed at a very early

period by surgical means—either by extirpation, by the Paquelin or galvano-cautery, or by strong caustics (nitric acid, chloride of zinc), etc. The remainder of the treatment is symptomatic, and consists mainly in an energetic local treatment of the glanders focus by incision. Inunctions of mercurial ointment (two to three grammes a day) have been repeatedly used with success. Iodine and arsenic have been recommended internally. Babes has obtained cures in animals by using his mallein (page 399), and has employed protective inoculations with success.

§ 79. **Foot-and-Mouth Disease** (*Aphthæ Epizoötiœ*).—The foot-and-mouth disease is, according to Bollinger, an acute infectious disease which is transmitted exclusively by infection from one animal to another. This disease, which is observed particularly in cattle, sheep, swine, and goats, less often in horses and dogs, is characterised by moderate febrile constitutional symptoms, and by the formation of blebs and ulcers upon the mucous membrane of the mouth (stomatitis aphthosa), in the clefts of the hoofs, and on the udder. For the poison to enter the body, an injury, according to Bollinger, is not necessary; it clings to the uninjured epithelial layer of the cavity of the mouth or enters the system through the lungs, and probably also with the food. The disease is very contagious. The course of foot-and-mouth disease is, as a rule, favourable, its duration, according to Bollinger, being usually twelve to fourteen days, rarely less. It generally terminates in recovery, and only young and cachectic old animals occasionally succumb to the disease if surrounded by unfavourable conditions.

The cause of the disease is, according to Stutzer and Hartleb, a pleomorphous micro-organism which is very pathogenic for mice and rabbits. It appears sometimes as an oval rod of variable length; under special conditions cocci, diplococci, and streptococci are formed, which are always embedded in a mucous envelope. Yeast-like bodies are sometimes present, or the bacterium changes into a streptothrix, and this into a thread. These metamorphoses can be studied by using culture media of different composition. The above interesting observations made by Stutzer and Hartleb need further confirmation.

Foot-and-mouth disease can be transmitted to man, but the predisposition of the latter to the disease is only slight.

Occurrence of the Foot-and-Mouth Disease in Man.—The *transmission* of the disease to man occurs, according to Bollinger, most frequently by drinking the uncooked milk of diseased cows (Hertwig, Jacob), or by infection of a wound, particularly on the hands of butchers, or as a result of milking cows with a vesicular eruption on their udders, or by contact with the saliva of animals having the disease.

The *symptoms* of the disease in man—for example, after infection through milk—consist in an ulcerative stomatitis, a catarrhal gastro-enteritis, accompanied by fever, and frequently in a vesicular eruption upon the hands, the face, and other portions of the body. If the poison is transferred through a wound—for instance, in slaughtering or milking an infected animal—the hand and forearm become swollen, vesicles form, and the patients complain at the same time of pain in the mouth and dysphagia; and later vesicles or pustules make their appearance on other portions of the skin, particularly on the face. The disease lasts five to eight days; and only when the ulcers in the mouth and on the hands take on a virulent character and heal slowly does the affection continue for two to four weeks. Secondary phlegmonous-suppurative inflammations occasionally make their appearance.

In a great majority of the cases the disease terminates in recovery, and only rarely, particularly in weak infants, causes death.

Treatment.—The treatment is essentially dietetic. Care should be taken to use only healthy milk. If the stomatitis is intense, it is an excellent plan to swab the mouth out repeatedly with a borax solution, and to employ mild cauterisation of the erosions and ulcers with silver nitrate in the form of a stick. The vesicular eruptions on the skin should be treated with ungt. lithargyr. Hebræ,* vaseline, boro-glycerine ointment, and particularly by dusting them with bismuth, iodoform, or oxide of zinc with starch (one to five to ten).

§ 80. **Hydrophobia** (*Lyssa, rabies*).—Hydrophobia is an acute infectious disease which occurs chiefly in the dog and related species of animals —wolf, fox, jackal, hyena. It consists essentially in a disease of the central nervous system, and is characterised by a long and extremely variable period of incubation.

Etiology of Rabies.—Rabies originates in a manner similar to syphilis—that is, by direct transference of the poison from the bearer to the receiver. The poison only takes root when inoculated into an injury of the skin or mucous membranes.

Rabies is almost always transmitted through the bite of a rabid animal, by which the poison is directly inoculated into the wound. The experiments of Roux and Nocard show that infection may even result from a dog which at the time when he bites or licks an individual is entirely healthy, but later becomes mad. According to Novi, he poison of rabies may also be transferred to animals by midges nd flies. Decomposition does not seem to destroy its virulence very on. In dead animals decomposing in the air, the virulence, accord-

* Unguentum diachylon.

ing to Travali and Brancaleone, could not be found after twenty-one days. In buried animals, the nervous centres were, in some instances, found virulent even after the lapse of forty-eight days; in other cases every trace of virulence had disappeared thirty-eight days after burial. The poison of rabies is destroyed by the digestive fluids. Zagari states that the virus of rabies loses its virulence very quickly when in contact with oxygen or air, as it also does in a dry medium and when the temperature is somewhat elevated; but in a space devoid of air, in carbonic acid, in a damp medium, and at low temperatures, it remains active for a long time. The poison of rabies, according to Pasteur, is always present in the fresh saliva, the blood, the spinal cord, and in the brain, salivary and lachrymal glands, the pancreas, and perhaps the mammæ of animals affected with hydrophobia. Bombicci has also found that the suprarenal capsules are always virulent. Di Vestea, Zagari, and Schaffer have shown that the rabies poison is spread throughout the body by the nerves, in addition to the blood and lymphatic vessels, and this nervous distribution of the poison is the essential factor in causing the diffuse myelitis of the central nervous system. The views upon the microbe of rabies are still divided. Gibier, Brigidi, and Bianchi think that a micrococcus is the cause of hydrophobia, while Pasteur has found a characteristic bacillus of which he attempted to make pure cultures, and which for a long time he considered to be the exciting cause of hydrophobia. Bruschettini has recently isolated a specific bacillus. When injected under the dura of rabbits, the animals died in about seventeen days after symptoms of paralysis had appeared. As yet the micro-organism of rabies is not known with certainty.

Inoculation Experiments.—Raynaud, Lannelongue, Pasteur, and others have transferred the disease to rabbits, by inoculating them with the saliva of persons affected with rabies. Pasteur obtained from the blood of these rabbits a micro-organism which he cultivated in veal broth; it was a bacillus somewhat contracted in the centre, and surrounded by a gelatinous substance. Pasteur at first believed, as we have said, that he had found in this bacillus the excitant of rabies; but he then produced the same disease by inoculating healthy human saliva, and he found the same micro-organisms in the inoculated rabbits. Vulpian and Fränkel obtained the same results by inoculating rabbits with normal saliva. Brigidi and Bianchi found in the saliva, and particularly in the blood of three individuals with rabies, before and after death, micrococci occurring singly or in pairs (diplococci). Only one of the attempts at inoculation in a rabbit was successful. Making use of Pasteur's method, brain substance was used for inoculation in this case. A portion of the brain substance taken from a child which had just died of rabies was placed in a wound in a rabbit's brain which had been exposed through a small opening in the skull and dura. The wound healed without reaction; the rabies began after the lapse of thirty-two days, and in two days

the animal was dead. The autopsy revealed complete cicatrisation at the point of operation, intact meninges, intact brain and spinal cord, and no suppuration. In the brain, spinal cord, and blood numerous micrococci were found. An attempt at inoculation with the brain matter of this animal gave no results.

Contrary to the views hitherto held upon the subject, L. Gibier has successfully inoculated birds (chickens) with hydrophobia, and from these he again transmitted the disease to rats by inoculation, which then died with the characteristic symptoms of rabies. Sometimes the inoculated birds withstood the disease. Microscopical examination of the brain of the diseased animals always revealed the presence of the above-described micrococcus of Gibier.

Transmission of rabies from the maternal animal to the fœtus *in utero* has been observed by Perroncito and Carita in rabbits and guinea-pigs.

Strengthening and Attenuation of the Rabies Poison according to Pasteur.—It is well known that Pasteur has artificially strengthened and weakened the virulence of the poison of hydrophobia. By continued transference of the poison in rabbits Pasteur obtained a very pure rabies poison which is constant in its effects. The fresh spinal cord and the medullary portion of the brain of such animals contain the strongest virus. If portions of the spinal cord and brain are dried, the virulence gradually diminishes proportionately to the length of time that the drying is continued. Pasteur has been able, by means of systematic inoculations with rabies poison of increasing virulence, to make dogs immune from the bite of mad dogs and from the artificially transferred rabies poison in its most potent form. In conjunction with these experiments on animals, Pasteur undertook, for therapeutic purposes, protective inoculation in individuals who had been bitten by dogs presumably mad (see pages 408–410, Treatment of Rabies). According to Tizzoni and Schwarz, the immunising substance, as in tetanus and diphtheria, is only found in the blood serum of the inoculated animals; it behaves like globuline, and probably belongs to the enzymes. Therefore they recommend that, as in tetanus and diphtheria, the blood serum of animals which have been rendered immune from rabies by inoculation should also be employed in man for prophylactic and curative purposes.

Action of the Rabies Poison.—The action of the still unknown rabies poison is probably similar to that of the tetanus bacillus. We saw in the chapter on Tetanus, which is so closely related to rabies, that the number of the bacilli in the system capable of demonstration is very small, and that the tetanus bacilli are destructive not by their numbers but by the formation of the poisonous products of their metabolism (toxines). The poison of rabies acts similarly to strychnine.

Rabies in the Dog.—The symptomatology of rabies in the dog is briefly as follows: A stage of incubation precedes the disease, and lasts generally three to five weeks, seldom less or more. The longest duration of the incubation stage, according to Bollinger, is eight months. During the incubation the wound from the bite usually heals very rapidly, without any particular inflammatory manifestations. In dogs, two forms of rabies are distinguished: the raging madness, or rabies, and the still rabies. The symptoms of rabies

vary in other respects, according to the race, sex, the state of nutrition, etc. of the animal. The raging madness usually begins with a stage of melancholia, which is characterised by great irritability of the animal, a peculiar restlessness, loss of appetite, dysphagia, and nausea. The dog shows a remarkable preference for all sorts of indigestible things, such as hair, earth, straw, dung, etc. The danger for man is the greatest during this stage, and is so much the more so since the first manifestations are often very insignificant. The initial stage, according to Bollinger, lasts one half to two to three days; then follows the stage of real madness—the irritation or maniacal stage—lasting three to four days. The characteristic manifestations of this stage, which only occur in paroxysms, are the change in the disposition, the continued loss of appetite, a peculiar change in the voice, an impulse to escape and run about, disturbances of consciousness, a marked passion for biting, and a rapidly increasing emaciation. A noticeable aversion to water is lacking, according to Bollinger, and only in exceptional instances does spasm occur in the muscles of deglutition. In the last or paralytic stage there is a constantly increasing weakness. The entire picture presented by the bristling animal is frightful to look at. The voice becomes constantly hoarser, the dyspnœa increases, and death generally occurs on the third, fifth, or sixth day, occasionally with partial or general convulsions. The termination, according to Bollinger, is always fatal; recovery has not yet been observed.

The quiet or melancholic form of rabies, which, according to Bollinger, makes up about fifteen to twenty per cent. of the total number of cases of madness, runs a more rapid course, as there is no maniacal stage. In the first stage the manifestations are the same as in the wild variety; then there soon follows a paralysis of the lower jaw, the mouth remains wide open, the voice becomes hoarse, disturbances of consciousness, rapid emaciation, and paralysis of the hind quarters follow, with death in two to three days.

The results of the autopsy reveal little which is positive. The most important changes, according to Bollinger, are a dark, thick condition of the blood, œdema of the brain, more or less pronounced catarrhal changes in all the mucous membranes, particularly in the respiratory and digestive tracts, frequently combined with hyperæmia and ecchymoses, hyperæmia and cyanosis of the parenchyma of various organs, and a high grade of emaciation. In the stomach and intestine there are usually found, instead of the normal food stuffs, indigestible foreign bodies of various kinds.

Hydrophobia in Man.—In man, rabies occurs by far the most frequently as the result of the bite of a mad dog (ninety per cent.), less often of cats (four per cent.), wolves (four per cent.), and foxes (two per cent.), and it always terminates fatally. Children, especially, often fall victims to the disease. According to the French statistics, one third to one fourth of all the cases of the disease occur in children under fifteen years of age (Ollivier). The question as to how many of those who are bitten by mad dogs are attacked afterwards by the disease has received very diverse answers. Bollinger is right in maintaining that the percentage of those attacked by the disease depends upon

whether one only takes into account the bites of really mad animals, or also of those which are supposed to be mad; and finally upon whether, and when, energetic prophylactic treatment of the wound made by the bite is adopted. This explains the discrepancies in the records, some of which state that a half, others a third, or even not more than five per cent., of those who are bitten become affected with hydrophobia. The cases of death from rabies in animals and in man have diminished remarkably in states such as Prussia, where there are stringent laws levied against all dogs found running about loose, or those thought to have hydrophobia, and where the muzzling of dogs is compulsory; indeed, in such states, as Flügge has stated, rabies in man has as good as entirely disappeared. As yet no undisputed case has been observed of the transmission of rabies from man to man.

In man, also, rabies is marked by a stage of incubation, generally of eighteen to sixty days, and occasionally of three to six months. An incubation of less than fourteen days is rare, and only in exceptional instances are there incubations lasting from six to twelve months. After the termination of the incubation period, during which the person who has been bitten feels perfectly well, and the wound has healed, usually with exceptional rapidity, the rabies begins with psychical disturbances (a melancholic frame of mind, excitability, restlessness, loss of sleep), loss of appetite, and occasionally, even at this stage, an antipathy towards liquids. The local manifestations at the point of the bite, which has generally healed, are not constant; occasionally there is observed an inflammatory swelling of the cicatrix, or the patient complains of pain, burning or itching. Fever is usually not present. The prodromal stage lasts, for the most part, about twenty-four hours, rarely longer. The first symptom of true hydrophobia in man is a spasm of the pharynx resulting in an inability to swallow. There now occur, in the form of paroxysms, severe respiratory and pharyngeal spasms caused by any kind of irritation, and especially by the sight of liquids—hence the name "hydrophobia." At the same time there are observed reflex spasms, for the most part general clonic spasms, less often tetanic. There is also a characteristic increased reflex excitability of the nerves of special sense; the patients suffer from a perverted sense of smell; they are over-sensitive to any noise, any draught of air, etc. They are usually afflicted with a nameless dread, which does not allow them to get any rest; the salivary secretion is increased; the mind remains, in the intervals, for the most part clear, but from time to time there are maniacal seizures, partly as a result of the terrible dread and the oppression in the chest due to the feeling of suffocation, and partly as a result of the attempts of others to re-

strain them. The pulse, which is at the outset full, gradually becomes weaker and more frequent, particularly after the paroxysms, when it reaches 120 to 160 or more. The temperature is generally only slightly elevated—38° to 38.5° C. (100.4° to 101.3° F.)—seldom reaching 40° C. (104° F.) or more. After the above-described manifestations of the second stage have lasted for one to two to three days, there occurs, with an abatement of the spasms and the difficulty in breathing and swallowing, a general exhaustion; death then follows within the next few hours, with convulsions, or quietly, or less often during a recurrence of one of the attacks of spasm. The consciousness is usually unclouded up to the last.

The duration of rabies in man is, in the majority of cases, two to four days, rarely more or less; the termination, as in animals, is regularly fatal.

Result of Autopsy.—The results of the autopsy in man are similar to what we have briefly described for rabies in animals—that is, the autopsy shows practically no characteristic changes. Schaffer called attention to an acute diffuse myelitis of the central nervous system in both the grey and the white matter, with marked degeneration of the nerve fibres and ganglia. Popoff often found in the nerve fibres of the central nervous system a very high grade of hypertrophy of the axis cylinder and an atrophic condition of the nerve cells, with conspicuous pigmentation. Popoff saw these changes chiefly in the motor centres. At all events, there is a pronounced parenchymatous myelitis, which affects principally the nuclei of the motor nerves (Charcot, Leyden, Erb).

Diagnosis.—In the diagnosis of rabies in man, the pharyngeal and respiratory spasms, the increased reflex excitability, and the paroxysmal nature of the manifestations of the disease are characteristic. Rabies can only be confused with tetanus of the head, the so-called *tetanus hydrophobicus*, which occurs in conjunction with wounds in the region supplied by the cranial nerves (§ 73), as in this also there are pharyngeal spasms. In such cases the patient's statements may point to the correct diagnosis. Tetanus, for the most part, occurs between the third to the eighth to the tenth day after the injury, and hydrophobia in the fourth to the seventh week after the reception of a bite from a rabid animal.

Prognosis.—The prognosis of rabies in man is regularly fatal. No certain cases of recovery from true hydrophobia have been observed.

Treatment of Rabies in Man.—Prophylaxis is of the first importance in the treatment. Strictly enforced police laws against allowing dogs to run about loose without their masters, also a high dog-tax, and laws compelling the use of muzzles, are of the greatest importance in lessening the occurrence and the spread of hydrophobia. As we mentioned before, it has been possible in this way to very materially diminish the frequency of the disease.

If a person is bitten by a mad dog, or by one supposed to be mad, he poison at the point of infection—that is, in the wound—must be destroyed as soon and as energetically as possible by careful disinfection with a one-fifth-per-cent. solution of bichloride of mercury or a five-per-cent. solution of carbolic acid, followed by energetic cauterisation with the red-hot iron, the Paquelin, or with chemical caustics (caustic potash, sulphuric and nitric acids). It is also a very good plan to immediately suck out the fresh wound. Excision of the wound or cicatrix, with subsequent cauterisation, may be efficacious, even though done several days or weeks after the injury was received.

Pasteur's Protective Inoculation.—It is well known that Pasteur has undertaken protective inoculations upon people who have been bitten by mad dogs, after he had made the discovery, as stated above, that dogs become gradually unsusceptible to hydrophobia when inoculated with rabies poison the virulence of which is gradually increased. Bordoni-Uffreduzzi has successfully practised Pasteur's preventive inoculation on dogs and on one horse. Tizzoni and Schwarz recommend the use of blood serum taken from animals (rabbits, dogs) rendered artificially immune, for prophylactic and curative purposes in man, since the immunising or curative substance is, as in tetanus, chiefly found in the blood serum.

Technique of Pasteur's Protective Inoculation.—Pasteur's manner of performing protective inoculation is as follows: A suitable amount of the dried spinal cord of an animal which has had rabies is pulverised with sterilised instruments, and to it is added sterilised veal bouillon. Lymph is thus obtained of varying virulence, according to the relative amounts of the constituents and the length of time that the cord has been dried. The material for inoculation is now injected with a hypodermic needle beneath the skin of the abdomen a little below the ribs, three fourths of a cubic centimetre being used for full-grown men and a little less for women, and half a cubic centimetre for children. Pasteur usually begins with a spinal cord which has been dried for fourteen days, then on the following day an injection is made of one dried for thirteen days, etc., until for the tenth inoculation a spinal cord is employed which has only been dried five days; the patients are then discharged. Sometimes, especially in bad cases—for example, in Russians bitten by mad wolves—according to Uffelmann's report, inoculations are made two to three times a day with rabies poison of increasing virulence. In this manner Pasteur has inoculated a great number of people who had presumably been bitten by mad dogs; of these people some died of rabies a short time after the treatment, and others later, and it is not impossible that death from hydrophobia may have occurred in some of the cases in consequence of the inoculation. But in a number of cases the protective inoculation has given the wished-for result. At all events, Pasteur's experiments are of the greatest scientific interest; but we must acknowledge, with Koch and Flügge, that Pasteur's protective inoculation for man has been

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used, for practical purposes, much too soon. A more thorough scientif investigation of the method should have been made before it was put i practical use. The protective inoculation should be employed with grea caution, for there is the danger that persons who would perhaps hav remained well without inoculation might acquire hydrophobia in conse quence of the inoculation, and die.

Bordoni-Uffreduzzi has likewise employed Pasteur's method of treatment with the best success, and in his statistics during the years 1886–'88 he reports: Two hundred and forty-one persons were bitten by animals which were experimentally proved to have rabies; in the case of two hundred and forty-five more, treated by Pasteur's method, the hydrophobia of the animals which bit them was rendered certain by physicians' certificates or by clinical observation; in forty-five persons the diagnosis of rabies was doubtful. Only six of the first group died; of the second, four; of the third, none; and consequently the mortality of the whole list was 1.88 per cent.

When the disease has once broken out, usually no treatment is of avail. We are then forced to limit ourselves to easing the great sufferings of the patient by symptomatic treatment. First of all, and as soon as possible, large doses of curare should be injected subcutaneously.

Pensoldt, in one case occurring in an eleven-year-old boy, employed without success very large doses of curare, injecting on an average 0.01 to 0.02 gramme every half hour, and in the course of one to two and a half hours the full fatal amount of curare was administered. Curare is very valuable in all cases as a symptomatic remedy for modifying the pharyngeal and respiratory spasms, but it does not possess an actual curative effect upon the disease. Remedies like chloral and chloroform are indispensable. For the severe convulsive and maniacal seizures of the patient the continuous administration of chloroform by inhalation is probably the best treatment.

Recently various remedies have been recommended for rabies. For example, Kartschewskji speaks well of the internal use of cantharides powder (0.06 gramme *pro die*) for a week, and at the same time the application of emplastrum cantharidum to the wound made by the bite. According to the experiments of De Blasi and Russo Travali, the poison of rabies has little power of resistance against the ordinary antiseptics and caustics, and they recommend creolin and lemon-juice. The latter, as is well known, has a great reputation as a popular remedy.

§ 81. **Poisoning by Insects, Snakes, Etc.**—From the bites of certain insects and snakes, poisoning, sometimes mild and sometimes severe may result, the nature of which we do not as yet fully understand Among the injuries caused by the stings of insects belong the bites o

gnats, fleas, bugs, etc., after which, as a result of the introduction of some irritating substance, there ensue local inflammatory manifestations in the form of redness and wheals, with itching and burning. Severer inflammation follows the wound inflicted by the sting which is situated in the posterior end of the bodies of bees and wasps. Their sting involves a decided poisoning of the wound, which occasionally presents itself as a very extensive, painful inflammation, with redness and swelling, and not rarely there may even be alarming constitutional symptoms. Many individuals are exceedingly susceptible to the stings of bees and wasps. The local inflammatory manifestations usually subside very soon. The constitutional symptoms which now and then occur—for instance, after the direct injury of a small cutaneous vein or a lymphatic vessel—consist sometimes in a peculiar state of collapse; the skin is cool, and covered with a clammy sweat, the pulse is small and rapid, and occasionally a condition of coma is observed. These threatening constitutional symptoms last usually only a few hours, but the patients generally feel noticeably feeble for several days. There are also many examples known of men and animals dying in a short time after being attacked by a swarm of bees or wasps. The nature of the wasp and bee poison is as yet unknown.

Injuries from Tarantulas and Scorpions.—I should also mention injuries produced by the tarantulas and scorpions of southern countries, with the subsequent extensive local inflammations, which never terminate fatally.

The *treatment* of the above-mentioned injuries, particularly the stings of bees, wasps, tarantulas, and scorpions, is best carried out with ammonia and antiphlogistic remedies. As Billroth says, bee-tenders employ scorpion oil as a kind of antidote for bee stings—that is, olive oil in which some scorpions have been kept.

Injuries from Venomous Snakes.—The injuries due to poisonous snakes are relatively rare in our zones as compared with the tropics. The nature of the snake poison is as yet unknown to us; it is probably a poisonous alkaloid which is contained in the secretion of the poison glands. In Europe there are ordinarily found only three kinds of poisonous snakes: the vipera berus, the vipera redii, and the vipera aspis. These poisonous snakes have two hook-shaped poison teeth, in which the excretory ducts of small glands empty. At the time of the bite the glands empty their poisonous juices into the wound. By drying the secretion from the poison glands of forty asps, Karlinski obtained fifteen grammes of a white amorphous mass, easily soluble in water and alcohol, a twenty-per-cent. aqueous solution of which corresponded in its action to the fresh poison coming from the poison

glands of the adder. According to Phisalix, Bertrand, and Calmett snake poison can be considerably weakened by heating it to 70°–75° C and by certain chemical substances. Various snake poisons, includin the poison of the cobra, are destroyed by permanganate of potash an chlorine compounds, but are very resistant to acids and most of th common antiseptics (bichloride, nitrate of silver). Calmette states tha immunity can be acquired by gradually accustoming the body to the poison, and supplying it with an antitoxic chemical substance (chloride of gold, hypochloride of sodium). The serum of immunized animals is antitoxic to snake poisons of different origins. According to Phisalix, a poisonous and an immunizing substance are found in vipers' blood simultaneously.

The *manifestations* after the bite of these poisonous snakes consist in a very painful local inflammation, in coagulation of the blood in the parts immediately adjoining the wound, in thrombosis of the blood-vessels, not infrequently in gangrene, vomiting, high fever, a feeling of anxiety, cramps, great weakness, etc. The affected portion of the body is subsequently often remarkably devoid of sensation. Occasionally death occurs in a relatively short time, preceded by an increasing state of collapse. The autopsy sometimes shows extensive thrombosis and at other times the latter are absent. If a person bitten by a viper redii survives the first two days, the prognosis is in general favourable. Out of 179 cases of bites by the viper redii only 5 ended fatally, with symptoms of asphyxia, intestinal hæmorrhage, cerebral compression, pulmonary œdema, and cardiac weakness. Death occurred in these cases in 4, 18, and 60 hours and 10 to 12 days.

The best treatment for these snake-bites is to immediately suck the wound—a procedure entirely free from danger—then to wash out the wound with bichloride of mercury, carbolic acid, absolute alcohol, etc., and, when possible, to cauterise the wound with some energetic liquid caustic or with the hot iron. To prevent the rapid absorption of the poison, it is a very good plan to employ the popular remedy of tying off the injured portion of the body—an extremity, for instance—as soon as possible, close above the bite. Energetic antiphlogistic measures are adopted for the local inflammation. Finally, the internal and subcutaneous administration of liquor ammonii fortior has been recommended, a hypodermic syringe full (one part liq. ammon. fort. with one to two to three parts water) being used as a subcutaneous injection; internally ten to twelve drops of the same mixture should b given many times each day. Karlinski praises the injection of on per cent. chromic acid and of chlorine water (Lenz) into the wour made by the bite and the surrounding parts. Large doses of alcoh

(whiskey) and energetic active motion of the muscles are in great repute among the laity.

The most dangerous poisonous serpents are the American rattlesnake and the cobra species of Asia and Africa. After injuries inflicted by the bite of these snakes there ensue extremely severe local inflammations which terminate in gangrene. The constitutional manifestations are like those in hydrocyanic-acid poisoning, consisting in a feeling of dread, oppression of the chest, cyanosis, delirium, convulsions, and stupor. Death follows, occasionally in a few hours, with symptoms of collapse; in fact, death not infrequently occurs before any local symptoms make their appearance. It is of practical importance to note that the poison may even have a fatal effect when in a dried condition or in an alcoholic preparation. According to Cohnheim, death from a poisonous snake-bite is in all probability caused essentially by the disintegration of the red blood-corpuscles.

The *treatment* is in general like that for the bite of a vipera berus. Richards and De Lacerda, basing their opinion upon experiments with the poison of the cobra, recommend the subcutaneous injection of a five-per-cent. aqueous solution of permanganate of potassium (eight to twelve grammes of the solution). Immediately after the reception of the bite a ligature should be placed on the proximal side of the wound, the ligature not being removed until several minutes after making the injection. In one case potassium permanganate was injected with success twenty-five minutes after the reception of the bite. The length of time within which a subcutaneous injection of potassium permanganate is attended with success becomes proportionately prolonged when a ligature is applied above the poisoned wound. If the poison has already caused constitutional symptoms, Richards's observations show that the injection of permanganate of potassium has no effect.

§ 82. **The Poisoning of Wounds by Indian Arrow Poison.**—This is perhaps the best place briefly to consider the wound infections produced, for instance, by the poisoned points of arrows used by the Indians. According to W. T. Parker, the arrow-points of the American Indians are poisoned with a devilish cunning, and the process is frequently kept secret. Vegetable poisons, especially curare or urari, or decomposing putrid substances (decomposing meat and blood, for instance, of dead enemies, decomposing liver, etc.), or snake poisons, made, for example, from the crushed heads of serpents, are employed. There is also a partiality for using the liver of an ox, which is pierced with arrows and allowed to decompose in the sun; crushed ants are also added to the mixture. The symptoms of poisoning differ according

to whether a vegetable poison like curare, or putrid substances, or animal poisons like those of snakes, or mixed poisons are employed. The action of curare, the real arrow poison of the Indians, is, as is well known, to paralyse voluntary muscles, except those of the heart and respiration. The cardiac and respiratory activity only succumb after poisoning with very large doses of curare. The American Indians still commonly use the arrow, in addition to firearms, for war and the chase. The point of the war arrow, according to W. T. Parker, is short and broad, and so formed as to enter easily between the ribs of a man. The hunting arrow is the weapon to be most feared. The Indians can shoot this about one hundred metres, and with as great accuracy as the best modern rifle. The arrow penetrates the tissues with great force, and can perforate the stoutest bones. Gutters are made in the shaft to permit the blood to escape from the wound. The point of the arrow is fastened to the shaft in such a manner that when it becomes wet, and consequently when it is in a wound, or when attempts are made at extraction, it easily becomes loosened and remains in the wound. The arrow-points are made of iron, pebbles, bones, glass, wood, etc. The Indians are greatly skilled in removing the points of arrows from wounds in which they have stuck. A counter opening is often made through which, after cutting off the shaft, the arrow-point is withdrawn.

Appendix.

Chronic mycoses: Tuberculosis (scrofula), syphilis, leprosy, actinomycosis.

§ 83. **Tuberculosis.**—Of the chronic infectious diseases of bacterial origin which are of importance for the surgeon, tuberculosis is very prominent. By tuberculosis (from tuberculum, a nodule) we understand an infectious disease due to a rod-shaped micro-organism, the *Bacillus tuberculosus* (Koch), and characterised anatomically by the formation of nodules, the so-called tubercles. On the 24th of March, 1882, Robert Koch announced to the Physiological Society of Berlin that he had found the cause of tuberculosis, and that the disease was alone produced by a single specific bacillus which he had made grow in pure cultures. The sensation created by Koch's discovery was exceedingly great, and his classical experiments in tuberculosis will always excite the profoundest admiration.

We shall here discuss mainly surgical tuberculosis—that is, the tuberculosis coming within the jurisdiction of surgical therapy, and particularly the very common tuberculosis of the skin, mucous membranes, lymphatic glands, sheaths of tendons, bones and joints, etc. In

ver part of the body the tubercle bacilli develop and multiply, lways give rise to the formation of characteristic tubercles—that ellular nodules devoid of vessels, which, after the lapse of a defi- ngth of time and in a certain stage in their development, die, by a process of cheesy degeneration.

gin and Structure of the Tubercles.—These tubercles (Fig. 334) te, according to the very careful investigations of Baumgarten, and others, in the following manner: In consequence of the of the bacilli in any particular tissue, there occurs, in the first a proliferation of the fixed tissue cells, which begins with the of caryomitosis and leads to the formation of protoplasmic, ial-like or epithelioid cells. The tubercles are consequently made up essentially of of epithelioid cells which in the connective-tissue of the original tissue, has been partly absorbed rtly pushed aside—the d reticulum of the tu- Some epithelioid cells ne nucleus, others two, still others are polynu- so-called giant cells—in there are often found a eat number of large oval The giant cells prob- iginate not by the fusion ral epithelioid cells but proliferation of the nu- a single cell. In spite vigorous growth of the

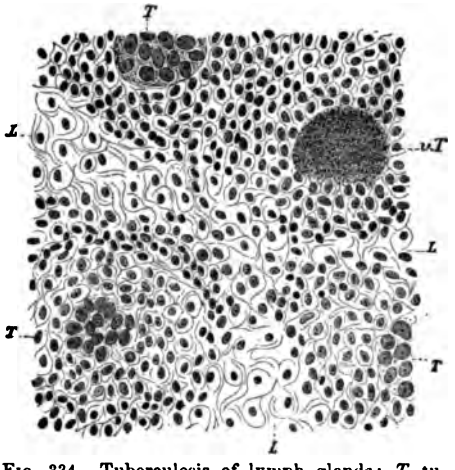

FIG. 334.—Tuberculosis of lymph glands: *T*, tubercle with giant cells in the centre, and large celled tissue between the separate tubercles; *v.T*, cheesy tubercle; *L*, tissue of the lymph gland, stained with hæmatoxylin. × 200.

ssue cells (connective-tissue cells; cells of the walls of the ves- ithelium) no new formation of capillaries takes place within the s. After the proliferation of the original tissue cells there occur, or later, inflammatory changes in the vessels of the diseased which lead to an emigration of the colourless blood-corpuscles, the periphery and then later in the centre of the nodules. dules, which are at the outset made up of large cells, thus come ade up more and more of small round cells. If the emigration ocytes occurs at a very early stage and masks the growth of the ells, it is possible for the nodules to appear to be made up of ells from the very beginning When the grey transparent nod-

ules, which are about the size of millet seeds, have reached the stage of the small-celled tubercles they are no longer capable of further development, and there now occurs a retrograde metamorphosis. The cells either undergo fatty or cheesy degeneration from lack of blood supply or from obliteration of the surrounding vessels by thrombosis and endothelial proliferation, or they break up into homogeneous masses as in coagulation necrosis. Frequently the tubercular foci become permeated with lime salts, and finally form mortar-like concretions. The typical death of the tubercle is by cascation or cheesy degeneration (Fig. 334 *v. T.*). The cause of these tubercles—that is, the cause of

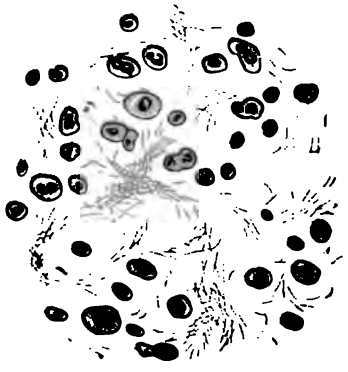

FIG. 335.—Tubercle bacilli; phthisical sputum dried on a cover-glass and stained with fuchsin and methyl-violet. × 700.

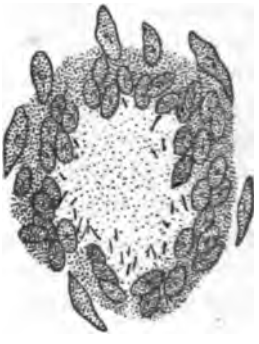

FIG. 336.—Giant cell with tubercle bacilli stained with Bismarck brown and gentian violet. × 800.

tuberculosis—is the above-mentioned rod-shaped bacillus discovered by R. Koch (*Bacillus tuberculosus*, Fig. 255, page 261).

Tubercle Bacilli.—The characteristic bacilli present in the nodules are found either in the interior of the cells—for instance, within the giant cells (Fig. 336)—or between the cells; also in the blood of those suffering from general tuberculosis, in the sputum of those with tuberculosis of the respiratory tract, in the urine in genito-urinary tuberculosis, in pus, etc. To Koch alone is due the great credit of having proved, by inoculations with pure cultures of his bacillus, that the bacilli present in tuberculosis are the sole cause of the disease.

Robert Koch's Tubercle Bacilli.—The tubercle bacilli are fine, generally slightly curved rods from 1.6 to 3.5 μ in length, incapable of spontaneous movement. They usually occur singly, rarely in pairs, and sometimes filaments are seen made up of five to six segments. Whether or not the bacilli form spores has not hitherto been determined. When the bacilli are stained there are occasionally seen bright vacuoles having a regular arrangement, which are suggestive of spores. The bacilli are extremely resistant, probably as a result of their very firm membrane or envelope; hence

do not lose their virulence, though dried for a month, or subjected to temperatures nearly reaching the boiling-point, or when subjected to ıposition or the acid gastric juice.

ıe cultivation of the facultative anaërobic, strictly parasitic bacteria out- f the animal body is accompanied with difficulties. They thrive best of ɔn the hardened blood serum of sheep, cattle, and in the incubation apparatus, at a temperature of 38° C. (98.6° to 100.4° F.). A tubercle containing or some similar substance taken from a slightly ; lymph gland can be used for the seed. Below and above 42° C. tubercle bacilli cease to grow. incubator temperature of 37° to 38° C., if the cul- very carefully protected from impurities and ecoming mixed with other bacteria, there develop ıe blood serum characteristic greyish-white, small les or crumbs, which become visible through the cope within five to six days, but to the naked eye fter the lapse of ten to fifteen days. From the the third week on, the appearance is very charac- . In a test tube the tubercle bacilli thrive ex- ;ly well upon meat-peptone agar to which has lded three to five per cent. of glycerine (Nocard, This glycerine agar is at present almost exclu- ısed for making pure cultures, and is displacing nd more the blood serum which is so difficult to . When tubercle bacilli are inoculated with the m wire upon glycerine agar, the first colonies observed along the line where the wire was about fourteen days subsequently. If the culture red to remain in the incubator for one and a half weeks longer the typical picture of a tubercle- culture will be obtained—that is, there will be on the agar an uneven, greyish-white, dry, lustre- ıss, which is made up of flakes, nodules, and cales (Fig. 337). The colonies consist of variously ing strings of bacteria clinging together (Fig. Tubercle bacilli also thrive in bouillon to which ɔ five per cent. of glycerine has been added, and ıve even been cultivated upon slices of potato alkaline) which were kept from drying by fus- ether the open end of the glass tube containing them (Globig, Roux). tubercle bacilli retain their virulence, though cultivated in artificial e media, for a long time. Koch has made pure cultures of these grow in a test tube for more than nine years, and he has observed only diminution of their virulence. The tubercle bacilli must be kept from it, as in direct sunlight they perish in a few minutes or hours, accord- he thickness of the culture. The dispersed daylight acts more slowly.

Fig. 337.—Linear culture of tubercle bacilli upon glycerine-agar five weeks old.

ine of Tubercle Bacilli.—Koch, Prudden, and others have attempted in the pure cultures of the tubercle bacillus obtained from man the

active principle (toxine) which causes the morbid conditions associated wi tuberculosis. According to the discoveries of Prudden and Hodenpyl, th poisonous substances are not found, as in many other species of fungi, in th nutritive medium, but they are, analogous to Buchner's bacterial protein fixed to the bodies of the bacilli in an extremely resistant form. The toxic action of cultures of tubercle bacilli lasts, according to Maffucci, about two years; it is not changed by subjecting them to drying for fourteen months, by exposing them to sunlight for thirteen to fifteen minutes or to the action of a temperature of 65° to 100° C. for several hours. Furthermore, they are not changed for a very long time during their sojourn in the human body. Dead tubercle bacilli can give rise to tuberculosis in animals, or rather to chronic marasmus with nodules resembling tubercles in the lungs, with pneumonic processes, thickening of the intima of the vessels, etc. Complete recovery from tuberculosis is not obtained by the death of the tubercle bacilli but the tubercular foci containing the dead bacilli must likewise be done away with or the tubercular poison itself rendered harmless. In fact, dead tubercle bacilli are said by Babes and Proca to contain more toxines than the living, because certain toxines are formed only in the dying bacilli, and are more easily set free from the dead bacilli than from the living. The cachexia of phthisical patients is caused mainly by the toxic substances formed by the tubercle bacilli. Richet and Hericourt have obtained from tubercular cultures a toxine which has a toxic effect upon tubercular rabbits, but none at all upon healthy ones.

FIG. 338.—Colonies of tubercle bacilli on coagulated blood-serum. × 700.

The poisonous action of tubercle bacilli is combated by certain protective substances (antitoxines) which are produced in the animal body. These antitoxines, which are also present in the cultures of tubercle bacilli, have a protective and curative action upon tubercular processes. For a description of Koch's tuberculin see page 431.

Staining of Tubercle Bacilli.—Different methods have been recommended for staining tubercle bacilli. The examination of sputum for tubercle bacilli is as follows: A portion of one of the ordinary yellow, tenacious lumps is taken from a mass of sputum, transferred to a cover-glass, upon which is then placed a second cover-glass, and the material to be examined is pressed between them. The cover-glasses are then removed from one another, allowed to dry in the air, and passed three times through a flame. While the cover-glass is held by thumb forceps, a drop of carbolised fuchsin is placed upon it, the preparation is held a moment over the flame, and this procedure is repeated several times, fresh staining solution being added if necessary. Then the stain is washed off with distilled water. The parts surrounding the bacteria are decolorised with fifteen to twenty per cent. nitric acid by moving the cover-glass back and forth a few moments in the latter until the deep-red preparation becomes greenish blue. Then the dissolved fuchsin

washed away in seventy per cent. alcohol, and the preparation is rinsed in distilled water and re-stained with methylene blue, by which everything is coloured blue except the bacilli, which still remain red. After washing in water the preparation can be examined immediately, or it may be dried, and mounted in Canada balsam.

Of the other methods of staining I should mention particularly B. Fränkel's, which is the best of the remaining ones, and can be quickly carried out. (Staining with hot carbolised fuchsin, then decolorising and counter-staining in a solution of fifty parts water, thirty parts alcohol, twenty parts nitric acid, and methylene blue to saturation, washing in water.) Gram's method is also useful. By the above-mentioned rules a stain can be given to sputum, fæces, pus from a wound, samples of pure cultures, etc. The staining of a section, and consequently of the tubercle bacilli in the tissues, is done in essentially the same manner (for instance, immersion for one hour in carbolised fuchsin, decolorising in dilute [ten per cent.] nitric acid for about one half to one minute, washing in seventy per cent. alcohol, counter-staining in methylene blue for two to three minutes, dehydrating in absolute alcohol, clarifying in oil, and mounting in Canada balsam.) Ehrlich's aqueous aniline-dye solutions are also much used for sections and cover-glass preparations. (At ordinary temperatures the object is immersed for at least twelve hours in Ehrlich's solution [aniline-water, fuchsin, or gentian violet], at higher temperatures for a shorter time, then for a few seconds it is washed in twenty-five per cent. nitric acid, and for several minutes in sixty per cent. alcohol, then double stained in Bismarck brown or a methylene-blue solution, depending upon whether it was first stained with violet or fuchsin, then washed in sixty per cent. alcohol and dehydrated in absolute alcohol, clarified in oil of cedar, and mounted in Canada balsam.) It is of practical importance to differentiate tubercle bacilli from the smegma bacilli which are so common on the external surface of the body. For this purpose Bunge and Trautenroth recommend a complicated decolorising method, consisting in treating the preparation with alcohol and chromic acid before staining it with carbol fuchsin.

Transmission of Tuberculosis to Animals.—The transmissibility of tuberculosis to animals by inoculation, by intravenous injection, and by allowing them to eat and inhale tuberculous substances, had been proved by Klencke in 1843, before Koch's epoch-making experiments had been made. Villemin (1865–'68) was the first to demonstrate by systematic experiments that tuberculosis can be transmitted from man to animals, and from animal to animal. These experiments were then repeated with positive results, particularly by Chauveau, Cohnheim, Klebs, and others. Then Robert Koch showed that tuberculosis could only be transmitted to animals by inoculation, by intravenous injection, and by inhalation when the material employed contained tubercle bacilli. In the first place, Robert Koch repeated many times successfully the inoculation experiments which had been performed upon guinea-pigs, rabbits, etc., with portions of tubercular tissue (nodules of miliary tuberculosis, tubercular pus, phthisical sputum, fungous material from joints, lupus, portions of scrofulous glands, nodules of bone tuberculosis). He then employed in a great number of transmission experiments pure cultures of tubercle bacilli, and by inoculating these into the subcutaneous

tissue, into the anterior chamber of the eye, and by injecting them into the peritoneal cavity and into the veins, and by causing them to be inhaled, he produced true tuberculosis, with its characteristic bacilli, which could be again and again successfully transmitted to other animals. So Koch has furnished in the most convincing manner the indisputable proof that tuberculosis is caused by specific bacilli. Koch's admirable work will be found in the Mittheilungen des Kaiserlichen Gesundheitsamtes, 1884. Almost at the very same time that Koch published his work upon the etiology of tuberculosis, Baumgarten, independently of Koch, had likewise found bacilli in the tubercles produced in rabbits by inoculation, but he did not make cultures and inoculations with them.

All animals are not equally susceptible to tubercle bacilli. Guinea-pigs, rabbits, and ruminants have a pronounced predisposition for tuberculosis, while dogs, rats, and white mice are immune from it. It is well known that man shows great variations in susceptibility to the poison of tuberculosis. Morrihy made the interesting observation that guinea-pigs which were inoculated with the toxines of tubercle bacilli and of the *Bacterium coli commune* did not acquire tuberculosis. Babes and Friedrich observed formations similar to the ray fungus in animals which were killed within twenty-five days after injecting into the common carotid salt solution containing a small quantity of tubercle bacilli. These did not appear in animals that were killed over thirty days after infection.

Tuberculosis of Cattle.—The tuberculosis of cattle, in which small and large nodules, even reaching the size of a walnut or potato, are formed, is, according to recent investigations, identical with the tuberculosis of man, and the presence of tubercle bacilli has likewise been demonstrated. Inoculation experiments have also given corresponding results. By the ingestion of meat and milk containing tubercle bacilli from tubercular cows (particularly those with local tubercular disease of the udder), tuberculosis may easily be caused in man. If boiled, the virulence of infected milk is destroyed; its poisonous character may be weakened by diluting it with milk which is free from bacteria (Bollinger).

Pseudo-Tuberculosis. Eberth has described a pseudo-tuberculosis of guinea-pigs. Changes simulating tuberculosis are found particularly in the abdominal organs especially in the liver, and to a less extent in the lungs. Some of the nodules present the appearance of miliary tubercles, others of small abscesses. In the centre of the nodules collections of micrococci are found, and the nodules themselves appear macroscopically either as spots of [illegible] surrounded by a zone of leucocytes, or as collections of pus. The tubercular [illegible] of Malassez and Vignal is probably identical with the pseudo-tuberculosis. Eberth also observed a tubercle-like disease in rabbits, and he found the micro-organisms to be [illegible] which were double the width of tubercle bacilli and rounded at the ends, [illegible] made up of shorter or longer segments, which were either [illegible] or in groups and collected in thick clusters. He regarded a coccoid form as the cause of pseudo-tuberculosis in man.

The Tubercle Bacillus of Birds. The [illegible] or virulent [illegible] of slight infective powers,

furnishes substances, according to Courmont and Dor, by means of which rabbits can be made immune from the effects of inoculation with the tubercle bacillus of man.

Combination of Tuberculosis with Carcinoma and Syphilis.—In rare cases there has been observed the simultaneous occurrence of carcinoma and tuberculosis in the same portion of the body; for instance, an eruption of tubercles may be found in the neighbourhood of a carcinoma of the stomach or larynx. In such instances the tubercle bacilli have gained access to the surrounding tissues through the carcinomatous ulceration (Zenkel, Hofmokl, and others). Ribbert believes that tuberculosis is the cause in some carcinomata of the formation of the primary subepithelial granulation tissue described by him (see Carcinoma). The simultaneous occurrence of syphilis and tuberculosis is also interesting; the syphilitic product, for example, may gradually take on a tubercular character from the lodgment of tubercle bacilli (Eisenberg, Leloir). In consequence of such a mixed tubercular-syphilitic infection, there will be observed corresponding affections—for instance, of the lymphatic glands and skin—which will only partially disappear under antisyphilitic treatment. According to Hochsinger, syphilis and tuberculosis occur as a mixed infection even in infants, and, in fact, this mixed infection may be congenital.

Origin of Tuberculosis in Man.—In the first place, individual predisposition, which may be congenital or acquired, is of particular importance in the acquirement of tuberculosis by man. This predisposition is due to general constitutional conditions and to local changes in the tissues, and especially to variations in the metabolism of the tissues exhibited by some individuals, as well as a change in the irritability of the cells. Foremost in this category stands scrofula, a congenital or acquired constitutional disturbance of nutrition. Climatic and other conditions peculiar to certain regions are also of great importance. In many places, such as certain high resorts or regions where lime industries exist, tuberculosis is almost unknown.

The tubercle bacilli or their spores, whose existence is still d ubtful, are contained in the atmospheric air, into which they get from the excretions, or the sputum, etc., of animals or man affected with tubercular disease. Tubercle bacilli are found particularly in the dust or the air in which phthisical sputum has opportunity to dry and become dispersed. They are also carried about by flies (Spillmann, Haushalter). To put a prophylactic restraint upon tuberculosis it is advisable first of all to introduce cuspidors into more general use, provided with a solution of bichloride of mercury (Cornet). Healthy people can very easily become infected with tuberculosis by constant contact with unclean phthisical individuals. Tubercle bacilli are taken into the body chiefly by the lungs; they also are taken into the intestine with the food, or they find entrance through an interruption in the

continuity of the skin, through fresh wounds, etc. Tuberculosis produced by inoculation into very small wounds or cutaneous abrasions is observed particularly on the hands of physicians, students, nurses, dead-house attendants, washerwomen, etc. According to Baumgarten, Tangl, and others, the bacilli, as the result of their growth and multiplication, always form at the point where they were absorbed, a local tubercular focus of inflammation. They may also gain access to the circulation, and by it be carried into the internal organs, particularly the lymph glands and bones (the marrow). The tubercular affection is, at the outset, always purely local (Baumgarten, Ponfick), but if the poison gets into the general circulation and so is distributed throughout the system, general miliary tuberculosis, or a flooding of the body as it were with bacilli, can take place.

Local tubercular disease originates with preference in the places where the tubercle bacilli easily find lodgment and are not mechanically swept away, as in the lungs, the lymph glands, in the capillaries of the bone marrow which have no walls, in terminal vessels, and especially in blood extravasations. According to Robert Koch, tuberculosis in man originates most frequently in the lungs. It is a matter of importance for the surgeon to know that tuberculosis of the skin and lymph glands can result from scratches, cutaneous eruptions, and ulcers in the skin. Czerny saw two cases which had been inoculated with tuberculosis by skin transplantation. Embolic tuberculosis of different organs, particularly the bones and joints, frequently originates from tubercular bronchial glands.

Extension of Tubercular Inflammation.—The extension of the tubercular inflammation, which, as we have said, is at the outset purely local, is dependent upon the multiplication of the bacilli. The extension either proceeds steadily by contiguity, or the wandering cells carry the bacilli into the adjoining parts and there form new foci, which either remain isolated or gradually coalesce with the primary focus. By the entrance of living bacilli into the circulation (blood, lymph) the tubercular inflammation may be distributed throughout the entire body. We observe an extension of the tubercular inflammation by contiguity when, for example, a tubercular inflammation of the bone marrow breaks through the bone and infects a neighbouring joint. In a similar manner the large serous cavities become diseased, usually by direct extension of the tubercular inflammation from one of the organs that form their walls (Weigert). Thus tubercular pleurisy originates, in the majority of instances, from a small pulmonary focus extending to the pleura, or from tubercular disease of the vertebræ, ribs, or lymph glands. Tuberculosis of the peritonæum is most frequently observed in

conjunction with a tuberculosis of the intestine, the female organs of generation, etc. Deposition of the poison directly from the blood into the serous cavities seldom takes place. Occasionally the extension of the tuberculosis can be traced along the lymph channels. In such cases there will be observed a corresponding formation of nodules in the course of the lymphatic vessels. From the lymph channels the poison passes into the lymph glands, then through the thoracic duct into the blood-vessels; or it may break into a vein directly, and in such cases cause a general distribution of the bacilli all through the system, so that nodules occur everywhere (general miliary tuberculosis), and then death usually follows in a short time.

In fourteen cases of general miliary tuberculosis, Weigert, by carefully examining the veins, was able thirteen times to demonstrate the place where the poison broke through into the veins, or into the thoracic duct, in the form of tubercular thrombi. Not infrequently there is an extensive formation of tubercles in the walls of the vessels. The bacilli occasionally lodge in the intima of the thoracic duct itself. In such cases there is observed a cheesy ulceration of the intima of the duct (Ponfick).

Detection of Tubercle Bacilli.—The detection of the tubercle bacilli is, as we have remarked, of the greatest importance for diagnostic purposes, particularly when found in the blood in general tuberculosis, in the sputum in tuberculosis of the respiratory tract, in the evacuations from the bowel in intestinal tuberculosis, in the urine in genito-urinary tuberculosis, and in the pus in tubercular disease of bones, joints, and soft parts. The bacilli can be most easily demonstrated in the sputum when they find a medium favourable for their nutrition, and can keep on multiplying secondarily. According to Robert Koch, the bacilli are particularly apt to be found where the tubercular process is in its inception, the cheesy, suppurating products, as a general rule, containing but few bacilli. Very often the tubercle bacilli cannot be demonstrated in tubercular pus; nevertheless, guinea-pigs inoculated with this pus will die of tuberculosis. The giant cells, in a process which has lasted a long time, will contain, for the most part, only a few bacilli.

Termination of the Tubercular Inflammation.—Wherever they may occur, both the nodules and the diffuse tubercular infiltration disintegrate and undergo cheesy degeneration. In this way, particularly in the skin and mucous membranes, tubercular ulcers are formed with a cheesy or caseous base after the inflammatory processes have broken through externally. In other cases, particularly in tuberculosis of the bones and joints, extensive suppuration occurs. The pus in the latter process has characteristic properties; it is usually thin, and contains cheesy masses. Occasionally, as in tubercular inflammation of the ver-

tebræ, extensive abscesses develop, which gradually sink downwards along the connective-tissue spaces. These are called congestion or cold abscesses (see Tuberculosis of Bone). In the bones and joints the disturbances excited by the tuberculosis, as we shall see later on, are very considerable.

The tubercular suppuration is mainly due to the tubercle bacilli, though in many cases there is a mixed infection with pus cocci—the staphylococcus and streptococcus.

A reactive inflammation usually takes place around the tubercular focus, encapsulating the latter, the organism trying in this way to protect itself from further infection. The single foci of tubercular inflammation may entirely heal, and they do this the more readily the smaller they are and the earlier and more completely they are removed by operative measures. Spontaneous healing of tuberculosis is due to a reactive inflammation in the neighbourhood of the tubercular inflammation. The cheesy masses become absorbed or encrusted with the salts of lime, the bacilli gradually die, and firm connective tissue takes the place of the tubercular material. But there is always the danger that the tubercular inflammation may break out afresh as long as bacilli capable of development remain enclosed in the original focus of infection. The bacilli, or rather their spores, appear to have great powers of resistance, which explains why tubercular inflammation recurs with such extraordinary frequency. The greater the number of the foci of disease, so much the more improbable is the recovery. All too often the latter is only apparent or temporary, and then suddenly the disease appears afresh. Every individual who has shown his susceptibility to the poison of tuberculosis by having had one attack of the disease is always in danger of a new outbreak.

Inheritance of Tuberculosis.—An important question for the physician is whether tuberculosis can be inherited—that is, whether the tubercle bacillus is transmitted from the parents to the fœtus, either at the time of conception or during its intra-uterine life.

Recent experiments and clinical observations upon animals prove the occurrence of a congenital tuberculosis in animals. Johne, Hertvig, and Csokor found tubercle bacilli in the fœtus of cattle. Koubassoff infected pregnant guinea-pigs with tubercle bacilli; both the mother and the fœtus became tubercular, and tubercle bacilli were found in each. Landouzy and Martin have also proved experimentally the existence of congenital tuberculosis. In man also the occurrence of tuberculosis developing *in utero* has been observed. Tubercle bacilli have been found in the blood and internal organs of infants, but usually without tubercles, the latter not developing until after birth.

Fœtal tuberculosis in man is, however, rare; it can result from tubercle bacilli in the spermatic fluid in case of tuberculosis of the genito-urinary

tract, and in case of tubercle bacilli in the blood of the father. It is well known that children of tubercular parents easily contract tuberculosis after birth, and hitherto it has been believed that tuberculosis always originates after birth, because the children in question inherit a predisposition for it and are exposed to a marked extent to infection by contact with their parents. I have no doubt that some cases of tuberculosis apparently originating after birth have already begun *in utero*, and consequently are of congenital origin. This has been recently confirmed by observations made by Birch-Hirschfeld. He demonstrated that the tubercle bacillus has the power of passing through the walls of the vessels from the maternal into the fœtal circulation. He had one case of a twenty-three-year-old woman who had died of miliary tuberculosis in the seventh month of pregnancy. In the placenta there were found, in the intervillous spaces and in the interior of the vessels of the villi, many tubercle bacilli; they were also found in the liver of the fœtus. Inoculations made with portions of the fœtal organs produced tuberculosis in guinea-pigs. Birch-Hirschfeld still holds to the general opinion that under normal conditions the placenta is impervious for finely divided foreign bodies or micro-organisms, but by pathological processes, or rather by the lodgment of micro-organisms, this filter is made pervious. The bacilli, as it were, grow into the fœtal portion of the placenta in the same way that the anthrax bacilli enter the pulmonary vessels after the inhalation of anthrax spores which Buchner demonstrated experimentally.

Brief Review of Tubercular Disease in the Various Tissues and Organs as far as it concerns the Surgeon.—Concerning the clinical course of surgical tuberculosis, the following brief statement will suffice:

Tuberculosis of the Skin and Subcutaneous Cellular Tissue.—Tuberculosis of the external cutaneous covering and of the cellular tissue is of frequent occurrence. The so-called lupus (§ 93, Chronic Inflammations of the Skin) is a special form of tuberculosis of the skin. Lupus occurs alone, or it may be a part of a tubercular constitutional affection. Other tubercular ulcerations of the skin occur, particularly in children and young individuals, either primary or secondary, for instance, to tubercular abscesses of the lymph glands and tubercular bone and joint disease. These tubercular ulcerations of the skin usually yield readily to surgical treatment. Various exanthematous skin lesions occur in the skin of tuberculous patients which are probably caused by the toxines of the tubercle bacilli, as the latter can usually not be demonstrated in the lesions (Boeck). In this category belong lichen scrophulosorum, several forms of eczema (eczema scrophulosorum), lupus erythematosus discoides seu disseminatus, etc.

The so-called anatomical tubercle described in § 76 is occasionally, though not always, a true tuberculosis of the skin.

Primary tuberculosis of the panniculus adiposus, particularly in young children, takes the form of firm, flat, subcutaneous nodes, which gradually extend, coalesce, and break through externally after the skin

has necrosed. In other cases they may evince a preference to gro into the deeper parts beneath the more or less uninjured skin.

Primary tuberculosis and primary tubercular abscesses of the de intermuscular spaces and connective tissue in the neighbourhood bones and joints are very rare. Tuberculosis in these regions is usuall secondary to tubercular disease of the bones, joints, and lymph glands In this category should be classed the congestion abscesses—that is, the so-called cold abscesses following tubercular disease of the bones or the joints, particularly those of the vertebral column.

Tubercular abscesses are very frequently observed. They are usually enclosed by a characteristic greyish or yellowish-grey membrane—the so-called abscess membrane—containing miliary tubercles. This membrane can be easily loosened or scratched off from the healthy adjoining parts. Only in rare instances is there seen a diffuse spreading of the tubercular inflammation into the muscular tissue. The above-mentioned abscess membrane is only observed in tuberculosis, and is consequently of diagnostic importance. It is lacking in syphilis, in which, in general, there is more frequently observed, in contradistinction to tuberculosis, a diffuse cheesy degeneration of the muscles, for instance.

Tuberculosis of Mucous Membrane—The Tongue.—Among tubercular affections of the exposed mucous membranes there is observed tuberculosis of the tongue which sometimes takes the form of a partly torpid, partly fungous ulceration, and at others of a deep-seated node with central softening. The tubercular ulcer of the tongue, with an indurated area surrounding it, may sometimes be mistaken for cancer, and tubercular nodes have a similarity to syphilitic gummata, but their local manifestations and the whole clinical course will, in the majority of cases, assure the correct diagnosis. In one case I saw the entire superficial surface of the tongue covered with tubercular ulcers, varying in size from that of a pin-head to that of a pea, and between them miliary tubercles were everywhere visible. The great majority of patients operated upon for tuberculosis of the tongue subsequently die of pulmonary tuberculosis; but still some complete recoveries have been recorded even in individuals strongly predisposed by heredity.

Tuberculosis of the Pharynx and Palate occurs mainly in tubercular children at the age of puberty and soon after, in the form of ulcers the size of a pea and larger, having a tendency to coalesce, and located on the palatine arches, the posterior wall of the pharynx, and the posterior surface of the velum palati. Between the ulcers there do not often fail to be miliary nodules, which are visible when the illumina

tion is sufficient. Tuberculosis of the pharynx and palate is very apt to be confused with syphilis. In the differential diagnosis it is to be noted that syphilis produces more loss of substance, while tuberculosis is more apt to give rise to extensive ulcerating surfaces which have a tendency to shrink and contract. In this condition permanent recoveries have also undoubtedly been obtained, but the majority of the patients die of pulmonary tuberculosis.

Nose.—Tuberculosis of the nasal mucous membrane (ozæna tubercularis) occurs in the form of a primary tubercular ulceration of the mucous membrane, or secondary to primary tuberculosis of the bones, particularly the superior maxilla.

Lips.—Severe tubercular ulcerations occasionally make their appearance upon the lips.

Rectum.—Some fistulæ of the rectum are, as the ancient physicians well knew, tubercular in character. The tubercular rectal fistula is characterised by a tendency to the formation of fungous granulations, by an extensive lifting up of the mucous membrane from the underlying parts, undermining of the skin, and by the formation of abscesses with sinuses. The prognosis of tubercular rectal fistula is very unfavourable.

Intestine.—Tubercular perityphlitis occurs after perforation of a tubercular intestinal ulcer. It gives rise to large tubercular abscesses, and yet patients who have them are often otherwise entirely well.

Genito-urinary Tuberculosis.—It has been my experience to find that tuberculosis of the genito-urinary apparatus runs a particularly unfavourable course, sometimes with great rapidity. Tuberculosis of the testicle and epididymis—originating either primarily or secondarily to tuberculosis of the vas deferens or the genito-urinary apparatus—usually occurs in young or middle-aged men, and even old men are not exempt. In general it is best, as soon as possible, to remove the tubercular focus in order to prevent the process from involving the other testicle or the spermatic cord, prostate, and bladder. Tuberculosis of the spermatic cord is characterised by an even thickening or a nodular swelling in the course of the vas deferens. Tuberculosis of the bladder, urethra, and kidneys is very typical, and belongs to the severest of the tubercular diseases. Tuberculosis of the bladder has hitherto resisted all attempts to cure it. The demonstration at an early period of tubercle bacilli in the urine is of great practical importance. For tuberculosis of the kidney or its pelvis, it is best, at as early a stage as possible, to undertake operative treatment in the form of nephrotomy or nephrectomy. I must refer the reader to my text-book of special surgery and to the text-books on gynæcology for tuberculosis of the

penis, vagina, and uterus. In rare instances inoculation with tuberculosis may take place on the external genitals as a result of coitus (Kraske, Schmidt). Tuberculosis of the mamma is, according to Billroth, Volkmann, and others, very rare, and its diagnosis is only possible in the later stages. In every case of tuberculosis of the breast the entire mamma, with the corresponding axillary lymphatic glands, should be removed.

Tuberculosis of Bones, Joints, and Tendon Sheaths.—For tuberculosis of bones, joints, and tendon sheaths the reader is referred to the paragraphs upon these subjects. It need only be stated here that tuberculosis of bones and joints is very common, and that the true caries of bones and joints—the so-called fungous inflammation of bones and joints—is with few exceptions true tuberculosis. Tuberculosis of bones and joints originates very frequently as a result of a traumatism. The tubercular joint inflammations are, particularly in children, secondary in nature, as they are most frequently due to an extension of the process from the bones. The tuberculosis of bones occurs chiefly as a tubercular osteomyelitis, which very frequently leads to the formation of large cold abscesses. Tuberculosis of the tendon sheaths manifests itself sometimes as a diffuse fungous disease and sometimes in the form of separate nodes.

Lymph Glands.—Tuberculosis of the lymph glands is exceedingly common, particularly in the neck. Areas of characteristic cheesy degeneration and suppurative softening develop either primarily in conjunction with a scrofulous hyperplasia of the glands, or secondary to tuberculosis of the lymph district in question. It is of very great practical importance that this glandular tuberculosis should receive operative treatment at as early a stage as possible, because, if the poison passes into the circulation, general miliary tuberculosis may readily follow.

Lymphatics.—That tubercular lymphangitis is of frequent occurrence can be easily understood from the frequency of tuberculosis of the lymph glands.

Blood-vessels.—The walls of the arteries, and particularly of the veins, become diseased both primarily from the blood and secondarily from neighbouring tubercular foci.

Diagnosis.—The diagnosis of tuberculosis is rendered certain when it is possible to demonstrate the presence of tubercle bacilli, when inoculation is successful, and the microscopic examination of the tissues reveals the above-described characteristic structure of the tubercles.

Prognosis of Tuberculosis.—We have already sufficiently outlined the prognosis of tuberculosis. Even in surgical tuberculosis, though radical

operative treatment may be adopted, a permanent cure is not so often observed as many enthusiasts believe; but the sooner the tubercular focus is removed, the smaller it is, etc., so much the more ground may we have for expecting a permanent, complete cure. But, as has been said, there is always the danger of a fresh recurrence of the disease even years later. For children, the prognosis, in general, is better than for adults; we often enough see spontaneous recovery take place in them from the most severe bone and joint tuberculosis. But we know, from the statistics of Billroth and others, that individuals who have suffered in their youth from tubercular disease of bone do not usually attain an advanced age.

Treatment of Tuberculosis.—The treatment of tuberculosis is partly local and partly constitutional. As it is a contagious disease, healthy persons should be protected, as far as possible, from infection. It is accordingly the safest plan to treat tubercular patients in hospitals; those with tubercular disease of the lungs should be treated in institutions built for that purpose. The local treatment of surgical tuberculosis—e. g., of the bones and joints—was, a few years ago, chiefly operative. At present the treatment is much more conservative. The operative treatment which used to be employed so vigorously is in part, and with the best results, becoming supplanted by a more chemical treatment, consisting chiefly in the injection of drugs either into the tubercular areas, or subcutaneously into some healthy part of the body, such as the buttocks, the muscles of the thigh, or the skin of the chest or abdomen, for the purpose of stimulating the metabolism or nutrition. Particular mention should be made of the aseptic injection of sterilised ten-per-cent. iodoform oil or iodoform glycerine—for example, into tubercular joints. I have had excellent results from this treatment, particularly in tuberculosis of children and young adults. To avoid iodoform intoxication, it is best to sterilise olive oil or glycerine and iodoform separately, by heating them at a temperature of 100° C. in the sterilising apparatus, and then to make with them a ten- to twenty-per-cent. mixture. Iodoform, in fact, appears to have a direct antitubercular action, as proved by the experiments of Baumgarten, Troje, and Tange. Furthermore, arsenic, three per cent. carbolic acid, tincture of iodine, and 1–5 per cent. iodine-iodide of potassium solution have been used for intramuscular and intra-articular injections. A solution of iodine, iodide of potassium and guaiacol (20.0 guaiacol, 5.0 iodine, 10.0 iodide of potassium, and 100.0 glycerine) may be injected into the buttock or the outer side of the thigh (Frassi). Chloride of zinc (1 : 10–15), balsam of Peru, calcium with phosphoric acid, oil of cloves (1 : 10 olive oil), vasogen, camphor, naphthol, copper salts, etc., have been used in a similar way. Lutton recommends the subcutaneous injection of 1 cu. cm. of the following: 5.0 phosphate of

sodium in 120 cu. cm. of equal parts of water and glycerine, to which is added 1.0 acetate of cupric oxide in 40.0 water and glycerine equal parts. The copper salts are said to have a temporary inflammatory reaction like tuberculin (see page 431). Koehler recommends the external employment of calomel powder, Bayer of five-per-cent. iodoform-vasogen, and Isnard of oil of turpentine (for injection into fistulæ and abscesses, or as an ointment, with equal parts of vaseline).

Arsenic has been recommended by Buchner both locally and internally. He believes that this remedy greatly increases the powers of resistance of the body, or rather of the cells. P. Bruns and others have obtained no satisfactory results from the injection of Kolischer's phosphate-of-lime solution (calc. phosphor. neutr. 5.0, aq. dest. 50.0, acid. phosphor. q. s. ad. solut. perfect. filtra, adde acid. phosphor. dil. 0.6, aq. destil. q. s. adde 100.0, and inject about 10 to 12 to 24 cu. cm.). Similar unsatisfactory results were obtained with Kolischer's lime-gauze packing. The gauze is impregnated with the above solution and contains ten times its weight of dilute phosphoric acid. Mosetig Moorhof speaks highly of the subcutaneous injection of about 3.0 teukrin (extractum teucrii, scordii depurat.) into the immediate vicinity of the diseased area; given internally (0.5 in gelatine capsules) it stimulates the appetite. Landerer recommends the local and particularly the intravenous injection of the following cinnamic-acid emulsion, which must first be rendered alkaline: Acid. cinamylici 5.0, ol. amygdal. 10.0, vitelli ovi unius, sol. natr. chlor. (0.7 per cent.) q. s. ut. f. emulsa 100.0. Landerer has been using of late two derivatives of cinnamic acid, betol, or cinnamate of sodium and betokresol. The cinnamic acid or its derivatives, when brought into the circulation, act only upon vascular tissues; they have a strong chemotaxic action, cause leucocytosis, and excite an artificial inflammation in the vicinity of the tubercular focus, with encapsulation of the tubercles and death of the bacilli (Landerer, Richter).

A. Bier has obtained remarkable success in tuberculosis of the extremities by employing permanent congestive hyperæmia, brought about by the application of a rubber tourniquet on the proximal side of the tubercular disease. This method of treatment was suggested to Bier by the well-known fact that the congested lung is immune from tuberculosis. Bier's passive congestion has been employed a good deal by Mikulicz, Zeller, the author, and others, and in part with good success. It is a good plan to use only slight constriction at the outset, to let it act for an hour at a time, and to change the place of application. Iodoform is used locally at the same time. It sometimes happens that the local process is made worse by this treatment, and the

latter has to be given up. As tubercle bacilli are killed by heat, Félicet, Maurel, Jeannel, and others recommend after operation the use of dry or moist heat (thermo-cautery, boiling salt water). This probably explains the excellent results from ignipuncture with the thermo-cautery or galvano-cautery. In other respects the local treatment of tuberculosis depends upon the part of the body that is diseased (see Regional Surgery). Tubercular joints are immobilised by splints (see Tuberculosis of Joints). The operative treatment of tuberculosis varies. It consists in excision of the diseased area, ignipuncture, scraping with a Volkmann spoon, synovectomy, resection of the joint, etc. In extreme cases the patient may be saved by amputation. Operative treatment should be combined when possible with medical and general treatment.

Iodine, arsenic, creosote, guaiacol, cod-liver oil, and lactic acid are the most common internal remedies. The treatment of the general condition of the patient is very important, and the course of tuberculosis is influenced very markedly by good food and good air and by a strengthening mode of life thoroughly carried out. It is also a good plan to employ baths, sea bathing, sea voyages, yearly sojourns in southern climates (Egypt, Madeira, Sicily), and to try high health resorts (Davos), etc. For prophylactic reasons, individuals with a predisposition to tubercular disease, or scrofulous patients, should be built up by a tonic treatment and kept from associating with those who actually have the disease.

Treatment of Tuberculosis with Koch's Tuberculin.—The treatment of tuberculosis with Koch's tuberculin, a metabolic product of the tubercle bacilli, is of great scientific interest. It is founded upon the idea of combating the tubercle bacilli and the poisonous products of their metabolism by corresponding protective substances (antitoxines). We know, in fact, that the bacterial toxines give rise to the formation of antitoxines which develop their protective and curative action chiefly in the blood serum of the body. Koch's tuberculin is, according to the statements of the discoverer, a glycerine extract from pure cultures of tubercle bacilli, a brownish-red fluid which contains, in addition to the active principle, a toxalbumen, indifferent colouring matters, salts, and extractives. In animals (guinea-pigs) Koch has obtained very satisfactory results with tuberculin; he has cured tubercular guinea-pigs, and has made others unsusceptible to inoculation with tubercle bacilli. In animals the tubercle foci are cast off in a state of necrosis after the subcutaneous injection of tuberculin.

The observations which have been made upon the use of tuberculin for tuberculosis in man have not been as satisfactory as in guinea-pigs. After its subcutaneous injection in tubercular individuals there generally occurs within about four to six hours a typical local and constitutional reaction which is best illustrated in tuberculosis of the skin, or lupus. The local his-

tological changes following the injection of tuberculin have been described by many authors. These changes consist in a very active inflammation in the parts surrounding the tubercular focus; the tubercle itself and the bacilli are not directly attacked. In consequence of the inflammation of the parts surrounding the tubercular focus the latter may be cast off under suitable conditions, but the typical necrotic destruction of the tubercular focus observed by Koch in animals following the action of the tuberculin does not appear to take place, as a rule, in man. In consequence of this inflammation of the surrounding parts the tubercular focus in lupus, for example, becomes very much swollen, a tubercular joint becomes extremely painful, etc. The constitutional effect of tuberculin observed even in healthy people after the administration of very large doses consists in fever and the other well-known febrile constitutional manifestations, which may assume a threatening character. I have frequently observed a rise of temperature to 41° C. (105.8° F.) and higher, and a pulse of 180 to 200. Examination of the blood reveals a temporary acute leucocytosis in which all forms of the white blood-corpuscles are involved. In consequence of this characteristic effect of the tuberculin upon the tubercular focus the remedy has great diagnostic value; only in exceptional cases does the typical reaction fail, as it did, for instance, in a case coming under my observation and subsequently operated upon, in which there was tuberculosis of the testicle and kidney. The typical reaction is occasionally observed even in people seemingly healthy, and then usually means a latent tuberculosis. In the case of an apparently healthy medical student, I observed, after subcutaneous injection of the tuberculin, a marked swelling of the cervical lymphatic glands and high fever; the cause of this proved to be an anatomical tubercle on the chin, microscopical examination of which after extirpation revealed typical tubercles.

There are numerous reports upon the tuberculin treatment, particularly of lupus, but permanent cures have only been obtained in very rare instances, and not infrequently the tubercular process has been made worse. Unfortunately the remedy has not always been used in properly selected cases. At present tuberculin is scarcely employed at all by surgeons. Though Robert Koch may not have discovered the means of curing tuberculosis in man, he is perhaps upon the right road to find a valuable means of assistance in the treatment of tuberculosis, particularly in its early stages. The conditions for rendering it possible to cure surgical tuberculosis are most favourable in those cases where the tuberculin treatment can be properly combined with the operative.

As to the technique of the method, I may say that I employ small doses and not too frequent injections, preferably under the skin of the back. I begin without exception with one milligramme of tuberculin for adults and half a milligramme for children, once or twice a week, gradually increasing the dose to 0.01 to 0.10 gramme. I do not use large doses—for example, 0.20 to 0.50 gramme or more. By the use of small doses once or twice a week the marked loss of weight, occurring so easily, is prevented, as are also the harmful constitutional symptoms. I have used the tuberculin in a great number of cases of surgical tuberculosis, and in some of them I have observed remarkable improvement, but no cures either in lupus or in any other tuberculosis of soft parts, bones, or joints. I am sorry to say that the im-

provements were only temporary in their nature, and many cases were even made worse.

The question whether tuberculin may occasionally favour the origin of a general miliary tuberculosis—that is, whether tuberculosis may be made general throughout the body by using the remedy—cannot be answered with certainty, but the possibility of this must be admitted (Virchow).

Klebs's Tuberculocidin.—Klebs has separated from the curative substances in Koch's tuberculin those which are noxious (which produce the necrosis) by precipitation with platinum chloride and phosphortungstic acid and by the addition of alcohol to the residue. The medicinal substance thus obtained, tuberculocidin, which belongs to the peptone group, has been found by Klebs to be of therapeutic value.

Antitubercular Serum.—The serum of animals made immune to tuberculosis seems to have in part similar properties to tuberculin. Maragliano inoculated dogs, asses, and horses with strong toxines of the tubercle bacillus, and employed with success the serum of these animals for tuberculosis in man. It is to be hoped that the time is not far distant when we shall possess an effective antitubercular serum which can be injected subcutaneously in tubercular subjects in the same way as the antidiphtheritic serum.

Cantharidate of Potassium.—Liebreich recommended the subcutaneous injection of the cantharidate of potassium (up to sixty grammes); its action is the same as that of tuberculin. B. Fränkel, Heymann, and Landgraf likewise obtained satisfactory results.

In this connection a brief description should be given of the nature and treatment of scrofula.

Scrofula.—By scrofula (from *scrofa*, hog) is understood a constitutional anomaly without anatomical changes that are capable of being positively demonstrated. It is characterised by a striking weakness of the tissues, or rather of the cells, rendering them incapable of withstanding injurious influences from without. Consequently we observe that scrofulous individuals, as a result of the slightest external violence, suffer from inflammations of every description, which may involve the skin, mucous membranes, or lymphatic glands. Scrofulous people, as we have remarked before, possess a pronounced predisposition to tuberculosis—that is, the scrofulous constitutional anomaly, with its local acute and chronic foci of inflammation, is an excellent soil for the tubercle bacillus. The relationship between scrofula and tuberculosis has been very frequently discussed, and since the discovery of the tubercle bacillus the connection between them has become better understood. We now assume that scrofula has nothing to do with true tuberculosis; it is rather a constitutional anomaly by which infection with the *Bacillus tuberculosus* is favoured.

If we have to deal with a cheesy or suppurative lymphadenitis, which is so often observed in scrofula, the decision as to whether we have to deal with tuberculosis or not is made solely upon the demonstration of tubercle bacilli. The same thing holds true of the so-called cold, scrofulous abscess in the soft parts, and the chronic inflammations of bones and soft parts. I am of the opinion that a pseudo-tuberculosis occurs in scrofulous individuals which is analogous to that observed in animals, which was described by Eberth, Ma-

lassez, and Vignal (page 420); it runs a course similar to true tuberculosis, though caused by other micro-organisms (cocci, bacilli), and not by the *Bacillus tuberculosus Kochii.*

The scrofulous diathesis is either congenital or acquired, as a result of unfavourable external hygienic conditions, a lack of proper nourishment, living in bad surroundings, etc. The most important marks of scrofula consist, in the first place, of a series of manifestations which are usually grouped together under the name of *habitus scrofulosus.* For convenience we distinguish two forms of scrofula: the irritable and the torpid form. Scrofulous individuals have in general a thin, delicate, transparent skin; they are more apt to be blond than dark, and are of a very excitable temperament (irritable form). In the torpid form of scrofula the skin is more puffed, the subcutaneous fat remarkably well developed, and the abdomen protruding. But all these manifestations are observed without scrofula, and the latter first becomes evident to the eye when local inflammatory manifestations make their appearance, particularly inflammations of the skin, mucous membranes, and glands. Of these the most constant are: Eczemas of every description which are so common; the catarrh of the throat, bronchi, stomach, and intestines; the pronounced conjunctivitis, blepharo-adenitis, and keratitis. The lymph glands are usually swollen and enlarged, with or without simultaneous cheesy degeneration. This is particularly the case with the lymph glands of the neck and submaxillary region, where great masses of enlarged lymph glands may exist. In this way the neck becomes very plump, and merges gradually into the head and trunk, as in pigs. The old-fashioned term of scrofula was derived from this comparison. In this caseous lymphadenitis the transitions to true tuberculosis are very common.

Treatment of Scrofula.—The treatment of scrofula must be directed first and chiefly towards overcoming the existing constitutional anomaly, particularly by the enforcement of proper hygienic rules—that is, by taking care to supply good nourishment, air, and light; by proper exercise in fresh air; by muscular exertion (gymnastics, swimming), etc. A residence at the seaside is particularly to be recommended in scrofula. This does not have a specific effect; it is only an adjuvant in the cure, exciting the appetite of the patient and thus improving his nutrition. The diligent use of salt baths (up to three per cent.) has a good reputation in the treatment of scrofula; they should be employed daily, or, in the case of weak individuals, two or three times a week and for ten to thirty minutes. Kreuznach, Nauheim, Oeynhausen, Reichenhall, and Heilbronn have the best reputation among the bathing resorts. They are particularly recommended on account of the iodine and bromine contained in the waters. The water is used to drink as well as to bathe in. The administration of cod-liver oil, fifteen to twenty to thirty grammes a day, particularly in winter, is likewise recommended. Cod-liver oil is an easily digestible fat of dietetic importance. Furthermore, scrofulous subjects should be cautiously toughened by degrees, to render them more capable of withstanding the frequent catarrhs of the mucous membranes. Every scrofulous local disease should receive proper treatment. In the matter of prophylaxis, too much emphasis cannot be laid upon the importance of protecting scrofulous children from contagion with tuberculosis, and from intercourse with those who have the latter disease.

§ 84. **Syphilis** (*Lues*).—By syphilis we understand a chronic infectious disease which, according to recent investigations, is most probably caused, like tuberculosis, by a characteristic fungus. By the transference of bacilli to apes, Klebs brought about inflammations some of which ran a course similar to the inflammation in syphilis, others to that in tuberculosis. Lustgarten, under Weigert's guidance, by using a special method, succeeded in demonstrating in tissues which had undergone syphilitic changes, and in the secretion from syphilitic ulcers, a particular species of bacillus (Figs. 339, 340) which is morphologically similar to the tubercle bacillus, but differs from it in shape, more frequently occurring in a slightly curved form, with knob-shaped enlargements at its ends. It also differs in its micro-chemical behaviour. While the tubercle and lepra bacilli, which are also brought to

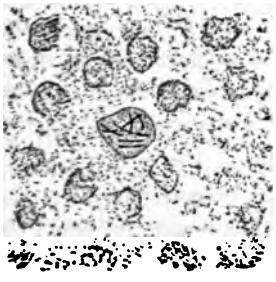

Fig. 339.—Wandering cells with syphilis bacilli. × 1,050 (Lustgarten).

Fig. 340.—Dry preparation of pus taken from a syphilitic sclerosis with syphilis bacilli. × 1,050 (Lustgarten).

view by Lustgarten's method, are not decolorised by hydrochloric or nitric acids (or only after being subjected to them for a long time), the syphilis bacilli rapidly part with their stain under the influence of these acids. The syphilis bacteria, as yet, are not distinguished by any other absolutely characteristic staining reaction. Lustgarten never found the bacilli free in the tissue, but always inside large oval or polygonal cells, chiefly wandering cells (Fig. 339). They occur here either singly or in groups of two to eight. The bacilli can usually be detected only in small numbers; they are found most commonly in cover-glass preparations (Fig. 340), less often in sections.

Method of Staining Syphilis Bacilli.—The syphilis bacilli are stained by Lustgarten as follows: The thinnest possible sections are treated with aniline-gentian violet for twelve to twenty-four hours, at the ordinary room temperature, then for two hours longer at a temperature of 40° C. in the incubator, washed in absolute alcohol for several minutes, then for about ten seconds in a one and-a-half-per-cent. solution of permanganate of potassium, and for one to two seconds in an aqueous solution of sulphuric acid, and then washed in distilled water. The latter three steps should be repeated

many times until the section appears completely colourless, then it is treated with alcohol, oil of cloves, and xylol-Canada balsam. Cover-glass preparations are treated in a similar way, except that, after staining in gentian violet, distilled water is used instead of absolute alcohol, and the separate steps in the process follow one another more rapidly. De Giacomi stains the preparations in Ehrlich's aniline-water-fuchsin solution, and then treats them with a chloride-of-iron solution.

The significance of Lustgarten's bacilli has been rendered somewhat doubtful by Alvarez, Tavel, Matterstock, and others. These authors have found in the preputial smegma, and in the secretion between the labia majora and minora and about the anus, bacilli having the same appearance and the same staining reaction as Lustgarten's syphilis bacilli. At all events, the etiological importance of Lustgarten's bacilli must be tested by further investigation, and the question must remain unsettled as long as it continues to be impossible to artificially cultivate the syphilis bacteria and to inoculate them successfully upon susceptible animals. By far the greater number of physicians are at present of the opinion that syphilis is caused by a specific micro-organism, but that this micro-organism has not yet been discovered.

Transmission of Syphilis to Animals.—Disse and Taguchi claim to have found in the blood of syphilitic subjects, partly by microscopical examination and partly by Koch's culture methods, spore-forming bacilli, by inoculation of which upon animals they have excited in the latter syphilitic disease. This statement must be regarded with suspicion, as should be the analogous reports of Martineau and Hamonic upon positive transmission experiments, since it has hitherto been the common experience to find that the syphilitic poison cannot be successfully inoculated upon animals. Furthermore, the experiments of Klebs relating to inoculation upon apes, as stated before, yielded doubtful results.

Origin of Syphilis.—Syphilis originates by the poison being directly transferred from one individual to another, particularly during coitus; less frequently it is extragenital in origin. It is sometimes hereditary. The broad condylomata (moist papules, see page 440) are the most frequent source of the contagion. It is doubtful whether the contents of the gummata, or in general of the local formations of the tertiary period of syphilis, are infectious. The transference of syphilis is only possible when the poison is inoculated in an injured spot, in some interruption of continuity—for instance, of the most superficial layer of the skin, which may often be very insignificant. The syphilitic poison is sometimes inoculated into two different parts of the body at the same time, so that two primary lesions are formed. The syphilis poison reproduces itself apparently only in the human organism, since indisputable inoculations in animals, as stated above, have not hitherto been observed.

Extragenital Modes of Infection.—The statistical data upon the frequency of the propagation of syphilis by extragenital infection vary greatly. According to Münchheimer, the number of cases of extragenital primary lesions published up to 1897 was 10,265, their frequency being on the average six to seven per cent. Generally speaking, extragenital infection is more common in women than in men, but this may be only apparently so, as primary lesions on the female genitals are often overlooked. According to Jullien and Fournier, an extragenital origin of syphilis in men occurs in from five to six per cent. of the cases; in women, on the other hand, in from twenty-five to twenty-six per cent. Krefting obtained similar figures on the basis of 539 cases (4.3 per cent. in men against 32.8 per cent. in women). According to Hahn, of 6,368 male syphilitics, only 131 (2.05 per cent.), and of 7,141 females, 159 (2.22 per cent.) showed an extragenital mode of infection. Mracek (Siegmund's clinic) gives an extragenital infection of one per cent. for men and fourteen per cent. for women.

The different portions of the body which are the seat of the primary extragenital infection of syphilis are, in the order of frequency, as follows: Lips, anus, finger, tongue, breast, abdomen, leg, palate. The comparative frequency of extragenital infection about the mouth is caused by kissing, by drinking utensils, pipe-tips, cigar-ends, tooth-picks, etc. Finger infection is particularly common in physicians and midwives. Syphilis can also be transferred by the primary lesion on the hands of physicians and midwives to their patients (Neisser). It is not infrequently transferred by infected instruments—for example, in dental operations, in shaving, etc. It is undoubtedly possible that syphilis may be transmitted by vaccination. Occasionally an entire family may become infected by a syphilitic nurse. The modes of extragenital infection are very varied; Bulkley has collected over a hundred. I doubt the assertion that syphilis caused by extragenital infection runs a more severe course than that due to genital infection, but it is true that the extragenital variety is usually recognised too late. This explains the family epidemics and other extensive syphilis epidemics.

Inheritance of Syphilis.—The question as to whether syphilis can be inherited is of great practical import. As a matter of fact, it has been proved that it can be. The inheritance of syphilis is possible in two different ways: by the poison attaching itself to the spermatozoön or the ovum, or by the healthy fœtus becoming infected from the blood of the mother (intra-uterine infection). It has been proved that syphilis may be inherited in the first of these two ways, and it appears to proceed from the father more frequently than from the mother. The transmission of syphilis by the father alone—that is, by the spermatozoa—has been proved by the fact observed by many authors, such as Hebra, Gerhardt, Weil, etc., that a non-syphilitic mother can give birth to a syphilitic child. The intra-uterine infection, on the contrary, has not hitherto been demonstrated; but it is theoretically conceivable and possible for a woman, who becomes syphilitic during her pregnancy, to infect her child by means of the blood-channels. But we should not omit to say that Bärensprung and Kassowitz, particularly, have vigorously contested the possibility of this intra-uterine infection, on the ground that it would be impossible for the syphilis poison to pass through the placenta. As a matter of fact, it frequently happens

that women with recent syphilis give birth to children who are healthy and remain so.

Still another question is of great practical importance. Can a syphilitic fœtus, originating, for instance, from syphilitic spermatozoa, infect its healthy mother? Such an occurrence is contested, like the above-mentioned intra-uterine infection of the fœtus from the mother, and as a matter of fact it has not as yet been proved.

The recent investigations of Birch-Hirschfeld in regard to the question of fœtal infection are exceedingly interesting (see also page 425). As he has maintained, the placenta, under normal conditions, is impervious for finely divided foreign bodies and micro-organisms, but the filter may become pervious by pathological processes, or by the lodgment in it of micro-organisms, so that then bacteria in particular, such as tubercle and anthrax bacilli, pass over from the maternal to the fœtal circulation, or rather grow through the tissues.

In fresh syphilis of the parents the fœtus usually dies before the end of pregnancy. In attenuated late syphilis of the parents the child is more apt to be carried to full term and then born with manifest signs of syphilis, or the syphilis appears soon after birth. Occasionally hereditary syphilis makes its first appearance very late, as Fournier in particular has recently shown. Such cases of syphilis hereditaria tarda are not infrequently confused with scrofula or tuberculosis. When the correct diagnosis is made in such cases, remarkable success can be obtained by the adoption of antisyphilitic treatment. In general the phenomena of congenital syphilis are the same as in the acquired. There are observed the same tertiary manifestations, with serious pathological changes in the skin, the viscera, and the bones (Parrot, Lannelongue). It is important to note that deafness or difficulty in hearing occur rather frequently in hereditary syphilis. Syphilis of the father is less dangerous for the children than that of the mother; syphilis of both parents is the most dangerous. The mortality among children with syphilitic mothers who have not been treated is, according to Étienne, enormously high: seventy-six per cent. die at birth or are stillborn, and over ninety-five per cent. of the few that are born alive die very young. Antisyphilitic treatment of the syphilitic mother during pregnancy reduces the mortality to eleven to sixteen per cent. (Étienne). The mortality and frequency of hereditary syphilis is particularly marked in the children of prostitutes (Werner).

When can a Syphilitic Individual Marry?—The question as to the duration of the contagious period of syphilis has been answered very differently. In my opinion it is impossible to fix the length of this period, and the question as to when a syphilitic individual can be given permission to marry is difficult to answer. In the great majority of cases the contagiousness is lost after three to four years of proper treatment. But it has frequently happened that wives have been infected by secondary syphilides six to ten to fifteen and even seventeen years after the primary lesion (Feulard). The predisposition of the infected individual is of great importance. Irritations of the mucous membrane—e. g., of the mouth from smoking—predispose to the formation of mucous patches which are very infectious. For this reason it is well to be cautious in granting syphilitics, who are heavy smokers, permission to marry (Feulard).

Symptoms and Course of Syphilis.—If we grant that syphilis is an infectious bacterial disease, its manifestations will be caused partly by the micro-organisms themselves and partly by the toxines which they form. Syphilis begins with the appearance at the point of infection of the so-called syphilitic initial sclerosis, or Hunter's induration, or the hard chancre. This specific formation is usually first capable of demonstration two to four weeks after infection, though sometimes sooner. The primary syphilitic initial sclerosis is generally a hard (indurated), painless (indolent) nodule, which gradually increases in circumference and then most commonly changes into an ulcer. In this way ulcers are formed with a hard, parchment-like base, or the order is reversed, and a vesicle develops first, which ulcerates and then indurates. Often enough the syphilitic initial infection is so small that it is easily overlooked, particularly in women, and the secondary manifestations occurring after a certain length of time are the first indication that syphilitic infection has taken place. The primary lesion is, as a rule, single, but multiple ones are occasionally observed. Only in rare instances is the syphilitic primary infection complicated by phagedænic changes—that is, by spreading gangrene.

Fig. 341.—Section through a hard chancre: *a*, round-celled infiltration; *b*, large mononuclear cells; *c*, polynuclear giant cells. Hæmatoxylin staining. × 300.

The microscopical examination of the syphilitic initial sclerosis, or of the primary syphilitic scleroma, shows that we have to deal essentially with a collection of round cells, epithelioid cells, and occasionally giant cells (Fig. 341). These cells break down after a certain length of time, giving rise to an ulcer; finally, the disintegrated cells are absorbed, and cicatrisation occurs. The chief element in the primary lesion consists in the formation of a chronic inflammatory infiltration of cells with subsequent cellular proliferation in the walls of the lymphatics and veins, with corresponding thickening of the same (Rieder). A similar proliferation of cells takes place later in the arteries (syphilitic endarteritis, see page 440).

Six to eight weeks after the infection, or later, the constitutional manifestations of syphilis make their appearance, and are due to the fact that the poison has been taken into the circulation from the primary focus of infection and carried through the entire body. The twelfth day is the earliest period at which the outbreak of the consti-

tutional manifestations has hitherto been observed. Occasionally the constitutional symptoms occur very late—for instance, in cases seen by Günz and Rinecker, one hundred and thirty and one hundred and fifty-nine days respectively after infection. Of the symptoms of syphilitic constitutional infection, the first to occur is an enlargement of the lymph glands in different parts of the body; for example, in the inguinal region, at the elbow, in the neck, etc. They can readily be made out by palpation. Then the skin and mucous membranes become diseased. We observe spotted (macular) or nodular (papular), exfoliating (desquamating) or large tuberous eruptions of the skin; also cutaneous ulcers, ulcers on the palate, the lips, tongue, anus, etc. Occasionally the spots upon the skin, particularly in women, have a whitish character (leucoderma syphilitica). In conjunction with a severe syphilitic exanthema there is sometimes observed a circumscribed atrophy, or thinning of the skin, in the form of bluish-coloured areas, in which the cutis forms very small folds. Following the above-mentioned manifestations in the skin and mucous membranes, there occur later syphilitic diseases of the internal organs, particularly the testicle, liver, brain, bones, joints, muscles, and peripheral nerves. The cutaneous eruptions are sometimes accompanied by jaundice and enlargement of the liver. Among the bones most commonly affected are those of the skull, the tibia, and the sternum. In the skull and nose, as we shall see in Regional Surgery, there occur very characteristic losses of substance. The syphilitic diseases of the central nervous system and of the peripheral nerves are of great practical importance. Degeneration of the posterior columns of the cord (tabes) is observed in syphilitic subjects particularly (Erb). The syphilitic poison may be deposited in all the organs and in every tissue and excite chronic inflammatory processes of various kinds, especially in the walls of the vessels, in the form of a syphilitic endarteritis, in which there is a thickening of the wall, particularly of the intima, and a narrowing, or even closure, of the lumen. The syphilitic endarteritis and arteriosclerosis also give rise to dilatation (aneurism) of the larger arteries, particularly the aorta. In other parts there are produced by the syphilitic inflammation either circumscribed growths or diffuse inflammatory infiltrations, with a tendency towards cicatricial formation. Among the circumscribed specific formations of syphilis should be mentioned, first of all, the gumma (Virchow), which is also called syphiloma (E. Wagner), and the broad condyloma (*condyloma latum*). The syphilomata, gummata, or gumma tumours, so called on account of their characteristic elastic property, are observed especially in the testicle, liver, spleen, meninges, periosteum, the marrow of the bones, and occasionally

also in the blood-vessels (Virchow, Baumgarten, and Langenbeck). They are either jelly-like formations, with few cells, or nodes made up largely of cells, and more or less like granulation tissue, with the single difference that the new formation of vessels is very limited. By the breaking down of the gummatous nodes extensive ulcerations occasionally result, particularly in the skin. The majority of tumours which make their appearance in the muscles are of syphilitic origin. The muscular syphiloma has a predilection for the sterno-mastoid, which, according to F. Karewski, is affected in one third of all the cases. In other cases the myositis syphilitica is diffuse. Many of the so-called "rheumatic muscular thickenings" can be referred to syphilitic processes (Braman). The broad condyloma is found particularly about the vulva and the anus. It presents itself in the form of a papillary, moist induration of the skin or mucous membranes, caused by serous transudation and cellular infiltration of the corium or mucous membrane. The tendon sheaths are only rarely diseased in syphilis. This occurs in the early period in the form of acute and subacute, serous or serofibrinous effusions (*hydrops tendinum*), or later as a gummatous teno-synovitis with the formation of painless nodes (Schuchardt).

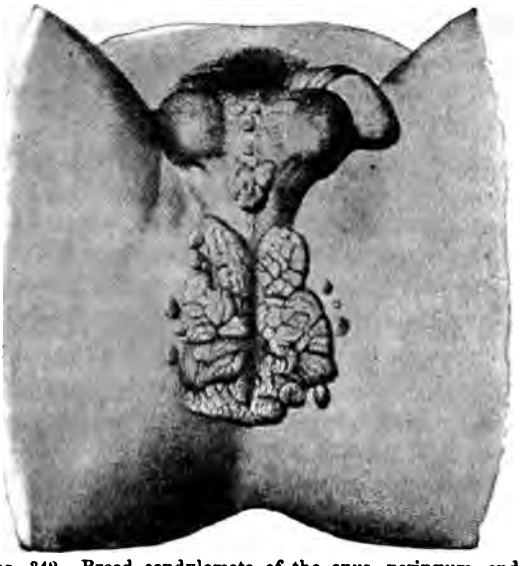

FIG. 342.—Broad condylomata of the anus, perinæum, and scrotum in a man twenty-eight years old.

The syphilitic diseases of joints (see also Diseases of Joints) which occur in the later stages of syphilis are particularly interesting. Anatomically they sometimes take the form of circumscribed ulcerations or carious processes, fibrillations of the cartilage with the formation of villous excrescences, and sometimes a proliferation of connective tissue or cicatricial tissue in the form of bands, or more diffuse growths. The ulcerative or carious processes are essentially due to the gummatous infiltrations, and the cicatricial tissue is the final result of inflammations of this sort.

Extensive hæmorrhages are observed, particularly in hereditary syphilis, as the result of local diseases of the vessels and the parenchyma (Mracek, *syphilis hæmorrhagica neonatorum*).

All these diverse manifestations of syphilis which have been so briefly outlined can be divided into three stages.

The first stage includes the incubation period of syphilis—that is, the formation of the local syphilitic sclerosis or the Hunterian induration at the point of infection.

The second stage begins, some six to eight weeks after the infection, with the occurrence of the first constitutional manifestations (swelling of the lymph glands, a macular, papular, or scaly eruption on the skin and mucous membranes), which are accompanied by more or less fever. The other cutaneous affections for the most part appear two to three—less often four to six—months after the infection. According to Siegmund, syphilis can be stamped out at this stage by proper treatment in about forty per cent. of all cases.

The third stage is characterised by the occurrence in the different organs of gummatous forms of inflammation.

Still a fourth stage can be added if so desired, including the syphilitic atrophy and the syphilitic marasmus. In general, the severe form of syphilis passing through all the different stages occurs when the disease does not receive proper care and suitable treatment. Not infrequently cases are observed which run a decidedly malignant course (*syphilis maligna*). The term malignant syphilis has been understood in very different ways. Two varieties can be differentiated according to the form of the disease, and the situation of the local manifestations. The really malignant form of the disease is characterised by a severe acute course with phagedænic changes in the primary lesion, multiple pus foci, severe pustular eruptions in the skin, etc.; this may be due, according to Tarnowsky, to a mixed infection with staphylococcus or other bacteria. Malignant syphilis may in other cases be characterised by the early appearance of tertiary symptoms, particularly in the internal organs. The occurrence of this form is said to be favoured, in Russia, by chronic malaria. Syphilis can also run a malignant course by attacking vital organs at an early period.

The Changes in the Blood in Syphilis, according to Biegański and others, consist in a marked leucocytosis which is due essentially to an increase in the number of the leucocytes. According to Reiss, the red corpuscles diminish in number but little during the primary stage, but more rapidly after the appearance of the constitutional symptoms, and also during the first part of the mercurial treatment; the percentage of hæmoglobin falls constantly from the first week of the primary lesion. Under the mercurial treatment

the number of red corpuscles and the amount of hæmoglobin in the blood increase again, and the leucocytosis becomes diminished.

Syphilitic Albuminuria.—Syphilitic lesions of the kidney are not frequent, and the albuminuria that occurs in the course of syphilis can be the result also of the mercurial treatment (Welander). The syphilitic albuminuria is occasionally observed at the beginning of the second stage, and is usually completely and permanently cured by antisyphilitic treatment. A second form of syphilitic albuminuria, occurring in the later stages of syphilis, is more unfavourable; it generally marks the beginning of a chronic nephritis (Horteloup).

Syphilitic Dental Deformities.—Hutchinson, in particular, has directed attention to the syphilitic deformities of the teeth in congenital syphilis.

Syphilitic Pseudo-paralyses.—Syphilitic pseudo-paralyses are observed, according to Parrot and others, for the most part in children two to three months old. Usually the children are suddenly unable to move the affected extremity, most frequently the upper; the extremity is painful, and generally in the region of an epiphysis—the lower epiphysis of the humerus, for example—a diffuse swelling and slight crepitation can be made out. The sensibility and the electrical excitability of the muscles are intact. The fingers can be moved a little. Generally, after a certain length of time, often a few days, the other upper extremity becomes diseased. There may be no other indications of syphilis, but usually traces of past syphilis are present in the parents. Complete recovery ordinarily ensues in from two to three months under antisyphilitic treatment with small doses of mercury.

Parasyphilitic Affections.—Under the name of parasyphilitic affections Fournier in particular has described such lesions occurring in the course of syphilis which have an undoubted etiological connection with syphilis, but are not really of syphilitic nature, and do not react to a specific treatment. These affections include leucoderma, various disturbances of the central nervous system and peripheral nerves, trophic disturbances of the muscles, bone, etc.

Syphilis and Carcinoma.—Occasionally syphilis is observed complicated by carcinoma—i. e., syphilitic tissue productions become the seat of a carcinoma, and then present important difficulties in diagnosis which are best solved by careful microscopical examination and antisyphilitic treatment.

The combination of syphilis with tuberculosis is discussed on page 421.

The course of syphilis is, in general, very chronic. It often happens that the syphilis remains latent for a number of years and then breaks out afresh with severe manifestations. After an interval of twenty to forty years local tertiary manifestations sometimes appear, particularly in the skin, the central nervous system, and bones. The syphilitic poison has great powers of resistance, as Fournier in particular has shown by numerous observations. Among patients with diseases of the brain and spinal cord, we find a great number who have previously had syphilis and had apparently recovered. Watraszewski has stated that injuries to the head or brain, which happen before or after syphilis is acquired, predispose to the occurrence of syphilis of

the brain early in the disease. What appear to be malignant tumours not infrequently prove to be gummata, which appear many years after an attack of syphilis that has apparently been cured.

Immunity from Syphilis.—In general one can only be attacked by syphilis once; that is, a patient who has once been infected becomes unsusceptible to the poison—in other words, immune. The immunity exists from the time the syphilitic enlargement of the glands takes place—indeed, as a rule, from the time when the primary initial sclerosis first appears (L. Hudels), and generally lasts till the death of the individual in question. Those who have completely recovered suffer only in rare instances a reinfection, as in other acute infectious diseases, and these reinfections are not unjustly doubted by various authors.

The Soft Chancre.—The so-called soft chancre (*ulcus molle*, see Regional Surgery), unlike the primary syphilitic scleroma, the hard chancre, is a local ulcerative process which usually occurs on the glans penis, the foreskin, vulva or labia, and may lead to inflammation and suppuration of the lymph glands but never produces the characteristic, syphilitic, constitutional infection There has been much discussion between two parties—the unitarians and the dualists—as to the relationship of the soft chancre to syphilis. At present the dualistic view is the most generally accepted—that is, that the soft chancre is an ulcerative process, remaining local, and has nothing to do with syphilis But weighty authorities including Hebra, Auspitz, Reder, and Kassowitz, still insist upon the unity of the two processes. This is not the place to enter more minutely into the discussion, and we shall only state that we also share the dualistic teachings advanced particularly by the French physicians, and we lay particular stress upon the fact that the chief means of distinguishing between the hard and soft chancre is not the difference in hardness, since, as a matter of fact, the so-called soft chancre may also show induration, but that the difference in the clinical behaviour is the single and only means of irrefutably proving that the primary syphilitic scleroma and the ulcerated chancre, which remains local, have nothing to do with one another. It is mainly the long period of incubation of the hard chancre, and the impossibility of auto-infection, which constitute the differences between it and the localised soft chancre. The latter does not have this long incubation, and is capable of being inoculated upon other portions of the bearer's body.

Gonorrhœa.—Gonorrhœa (see Regional Surgery) also has nothing to do with syphilis. Gonorrhœa is either a simple or an infectious catarrh of the urethra or of the genital tract, and is produced by a micrococcus, the so-called gonococcus, first discovered by Neisser. Neisser himself states that not every case of gonorrhœa is due to this coccus, but that there is also gonorrhœa which is not a specific infection. Bockhardt excited gonorrhœa with pure cultures of the gonococcus in a paralytic patient during the terminal stage of his cerebral disease.

Treatment of Syphilis—Treatment of the Syphilitic Primary Infection—If syphilis is a bacterial disease, as it undoubtedly is, it would seem a necessary part of the treatment to extirpate the place of primary

infection—that is, the chancre—as soon as possible; and consequently Neisser, Bäumler, and others have recently proposed a treatment of this sort in order to prevent, or at least to modify, the constitutional manifestations by removal of the primary germ focus. On the other hand, the propriety of excising the primary syphilitic scleroma has been contested on the ground that this syphilitic primary infection is, after it has made its appearance, the expression of a constitutional disease, and consequently its extirpation is of no avail. I consider this view incorrect; it contradicts our present knowledge of the origin of constitutional disease from a primary focus of infection. Like Neisser, Bäumler, and others, I also try to destroy the primary point of infection in syphilis by excision, by the galvano-cautery, etc., in every suitable case as early and as energetically as possible, before the manifestations of the constitutional syphilitic disease make their appearance. It is only by very early excision of the primary lesion that it is possible to prevent the outbreak of the general infection. I treat every suspicious ulcer in the same way, even when its syphilitic character has not been rendered certain. Bäumler is right in recommending the removal of the already infected glands in suitable cases in addition to the excision of the primary lesion. Syphilitic ulcerations which appear later are best treated with dusting powders, particularly iodoform, dermatol, oxide of zinc, bismuth, or boric acid, after previously cauterising them with solutions of carbolic acid (1 to 2 alcohol) or chloride of zinc (1 to 8), caustic potash, formalin 10 to 40 per cent., etc. Washings with bichloride of mercury (0.1 to 100 water), three-per-cent. solutions of carbolic acid, etc., are also to be recommended. The rest of the treatment for local syphilitic disease is conducted, as far as necessary, according to general surgical principles.

Treatment of the Syphilitic Constitutional Infection.—For the treatment of the syphilitic constitutional infection we have two remedies at our disposal: mercury and iodine. Opinions differ as to the value of these substances. According to my own experience, mercury should be used in the early period of constitutional syphilis, and later on iodine and mercury in alternation. There is some difference of opinion as to when the mercurial treatment should begin. Some authorities claim that it should be begun as soon as the primary lesion appears, while others wait for the constitutional symptoms, e. g., the glandular enlargements. In case the diagnosis is certain the treatment may begin early—by way of prevention, as it were, and in this case the disease not infrequently runs a very mild course. The methods of administering mercury are by inunctions of ungt. hydrarg., by subcutaneous injections of the salts of mercury, and by the internal use of mercurials.

Of the different methods of treating syphilis, the best in my experience is the inunction of ungt. hydrarg. It is of the greatest importance that the inunction treatment should be carried out systematically, as good results can only be secured in this way and a cure guaranteed. In the treatment by inunction, three to five grammes (in adults) of blue ointment are rubbed daily into different areas of skin for about twenty minutes, following a definite order (both arms, the thigh, the forearms, the legs, chest, abdomen, and back). After all portions of the body have been inuncted, the patient then takes a bath and begins the inunctions anew, following the same order. The ointment must be rubbed in over as large a skin surface as possible, and in order that the patient may also breathe in the vapour of the mercury, he should remain in the same room for some time, wear warm clothing, etc. I usually employ three grammes for each of the first ten sittings, four for the next ten, and five grammes for each of the next ten. The mouth must be kept scrupulously clean, to avoid a mercurial stomatitis. The teeth must be cleaned many times a day with a soft toothbrush wrapped in mull, using tooth-powder and water. Every two to three hours the patient should gargle his throat with a one- to two-per-cent. solution of chlorate of potash, boric acid, etc. Smoking should be absolutely forbidden. If, in spite of all this, signs of stomatitis appear, greater care must be bestowed upon the mouth, or eventually the dosage of mercury diminished or the mercury stopped entirely. Unna recommends for inunctions a preparation of mercury, lard, and green soap, which after being put on the area of skin in question is rubbed in with the hand, which is dipped in hot water 4 to 5 times. He claims that this soap has a prompter and stronger action and does not soil the underclothes.

For subcutaneous injection with the hypodermic syringe various double salts are used, such as mercuric chloride, sodium chloride (hydrarg. chlor. corros. 0.1, sodii chlor. 1.0, aq. destil. 10.0, one half to one syringeful a day), or albuminate compounds of mercuric chloride; 0.1 gramme of the selected compound is injected daily into different portions of the body, particularly the breast and back, or intramuscularly in the gluteal region. The injections which used to be given daily were very inconvenient, and they are at present made less often—every five to eight days, for example—and preference is given to the use of insoluble salts of mercury, particularly calomel, hydrarg. oxidum flavum, etc., which are best injected intramuscularly in the gluteal region. Injections of calomel (0.05 to 0.2 gramme) in glycerine, oil, or salt water, at intervals of four to eight days, are used very frequently. Kopp, Strümpell, and others recommend injections of an emulsion of calomel in water with sodium chloride (calomel vap. parat.

5.0, sod. chlor. 1.25, aq. destil. 50.0, one gramme to be injected once a week, altogether four to six times). Calomel oil (1 to 10) is exceedingly good, two syringefuls on the first day, and two more fourteen days afterwards, or every eight days one syringeful (0.1 gramme calomel; Neisser, Doutrelepont, Bergmann). Prochorow recommends one to two per cent. cyanide of mercury (one hypodermic syringeful—altogether about twenty to twenty-five injections). Mention should be made of the following methods of injection: Hydrarg. oxid. nigr. or hydrarg. oxid. rubr. laevig. 1.0, gummi arab. 0.50, aq. destil. 10.0, or 1 to 10 ol. oliv.; a syringeful of this to be injected altogether three to five to seven times at intervals of a week. In a similar manner use is made of the very excellent hydrarg. oxid. flav. 1.0, gummi arab. 0.25, aq. destil. 30, or 1 to 30 ol. amygdal. or olivæ (Strümpell), every week a syringeful in the gluteal region, four to six to eight times. These injections are not so painful as calomel injections, and the formation of abscesses is more easily avoided. E. Lang has practised injections for many years, with the best results, with oleum cinereum—i. e., a fifty-per-cent. mixture of blue ointment with lanolin and olive oil. Every five to eight days, 0.1 to 0.15 of a cubic centimetre of the ointment is injected in the back or rump. The thymolate and the salicylate of mercury have been used a good deal for injections—e. g., hydrargyri salicyli 0.20, mucil. gummi arab. 0.30, aq. destillat. 60.0, six to twelve injections at intervals of two to three days. Injections of the salicylate are sometimes followed by a rise of temperature, night-sweats, polyuria, and other sequelæ. Leichtenstern and Eich observed recurrences in more than thirty per cent. of the cases treated by the salicylate of mercury, and in some of these cases the recurrence took place soon after the completion of the cure. Lassar recommends for severe forms of syphilis injections of five per cent. bichloride. The mercurial injections are somewhat painful, and must be made by the physician himself and under antiseptic precautions, in order to prevent the formation of abscesses. The injection method is a very convenient one for dispensary and private practice, but I doubt whether it is as efficacious as the inunction treatment. In my experience, recurrences are more common after the injection treatment than after the inunction method. The action of the insoluble salts in particular is weaker and not so lasting, and yet, in spite of this, poisoning is not infrequently observed. In a few cases injections of insoluble salts of mercury have been followed by pulmonary embolism, with paroxysms of coughing, cardiac weakness, bloody expectoration, and circumscribed infiltration of the lungs (Harttung). Tommasoli praises the curative action of injections of the blood serum of lambs (2 to 8 cubic centimetres daily). This

blood-serum therapy of syphilis is analogous to the treatment of other infectious diseases with the blood serum of animals which have been made immune from the infectious disease in question. These injections of the blood serum of immune animals (sheep, dog, rabbit) are, according to the view of most authorities, without therapeutic value. The serum of individuals with tertiary syphilis has also been injected into those recently infected, in order to furnish the latter with the antitoxine of syphilis, and thus make them immune to the secondary manifestations (Bock). These experiments will also require further trial before we can give a correct judgment in the matter.

Internally the following preparations are especially used: Bichloride of mercury (0.05 to 0.1 gramme *pro die*) and calomel (0.05 to 0.1 gramme, three times a day in pill or powder). Calomel is also given in large doses (e. g., 0.1 to 0.5 gramme morning and evening), when it is desired to obtain the effects of mercury quickly. Lustgarten and others have recommended hydrarg. tannicum oxydulatum in powder or pill form, according to the following formula: Hydrarg. tannici oxydulat. 4.0 grammes, extr. et pulv. liquirit. q. s. ad. pilul. no. 60; three to five pills a day for adults, for children smaller doses of 0.02 to 0.03 gramme. Gamberini, Schadeck, and others recommend hydrarg. carbol. oxydat. (hydrarg. carbol. oxyd. 1.2 gramme, extr. et pulv. liquirit. q. s. ut f. m. pilul. no. 60, two to four pills daily). Schadeck has also recommended this remedy for subcutaneous injections (hydrarg. carbol. oxyd. 2.0, mucil. gummi 4.0, aq. destil. 100.0, one syringeful [0.02 of the hg. salt] every two to three days). Recently the salicylate of mercury has been much used internally (1.0 gramme in 60 pills, three to four pills daily).

Excretion of Mercury—Mercurial Cachexia.—According to recent investigations, mercury is excreted mainly in the fæces and in the urine, but in the latter not constantly. The excretion of mercury in the fæces continues for weeks or months after the treatment has ceased. Schuster found the fæces free from mercury one year after the cure. Vajda, Paschkis, and Oberländer came to the conclusion that mercury is sometimes retained within the body for years. In former times, especially, the use of mercury was dreaded because there would occasionally arise an incurable mercurial poisoning (mercurial cachexia). It is a generally accepted fact at the present time that this trouble can be avoided with certainty by careful use of the remedy.

Iodine is suited, particularly for the late period, for the gummatous inflammations, though it is also given by many—Zeissel, for instance—in the early stages. He only employs mercury late in the disease and in necessary cases. Iodide of potassium or iodide of sodium is given in a dose of about one to two grammes, seldom more (8 to

10 grammes), daily, best in aqueous solution. In suitable cases very large doses of iodide of potassium (20 to 30 grammes and more *pro die*) have been administered, accompanied by a milk and meat diet, with bromide of potassium and antipyrine to prevent the iodism and headache. Many recommend the simultaneous use of the iodine and mercurial treatment. Güntz praises bichromate of potassium, particularly for syphilis maligna (one bottle of chromium water every day with 0.03 gramme of bichromate of potassium). In syphilis maligna mercury should be used with the greatest caution. Iron and the quinine preparations are to be recommended, as well as a strengthening diet, proper hygienic measures, and iodide of potassium, together with a suitable local treatment.

The proper nutrition of the patient should be carefully attended to; a moderate amount of alcohol should be permitted, and exercise in the fresh air is desirable, etc. In the inunction treatment, particularly, attention should be paid to keeping the bowels regular.

For recurrences, constitutional treatment, best by inunctions, should always be undertaken again for a time.

It is well known that occasionally, after an apparent cure which may have lasted years, severe local and constitutional manifestations make their appearance. For preventing this, Fournier and Neisser have urgently recommended the use of mercury or iodine for one and a half to two years at proper intervals after the syphilis has been apparently cured. When possible, I usually give a course of inunctions every half year for four years after infection, even in the cases that are cured. I alternate a mild course with a more severe one.

In children with hereditary syphilis, for example, it is an excellent plan to use mercurial baths (2 to 5 grammes in a bath lasting half an hour). The internal administration of calomel (0.005 to 0.01 gramme twice daily) or of bichloride of mercury (0.005 gramme *pro die*) easily produces disturbances of digestion.

It is a very good plan to carry out the inunction treatment in some resort where baths or mineral waters can be employed. In this way the metabolism is stimulated—i. e., both the syphilitic poison and the mercury are eliminated in greater amounts, so that the latter can be employed in larger doses even in weak patients. I can recommend Tölz, Wiesbaden, and particularly in old cases the sulphur springs in Aix, Neuendorf, etc. In a resort of this sort the patient devotes himself entirely to his treatment, which he can often not carry out at home.

In the treatment of syphilis, the healthy individuals with whom the patient constantly comes in contact should always be protected from infection by proper precautions.

It is probable that the mercurial treatment of pregnant women can also exert a direct influence upon the syphilis of the fœtus infected at the time of conception, as Zweifel, Gusserow, and others have proved that various drugs, like chloroform, salicylic acid or iodine may pass from the maternal into the fœtal circulation. Syphilis and tuberculosis are the two greatest scourges of the human race, and they will necessarily prove very disastrous to future generations as well. It is of the greatest importance that syphilis should be combated with the greatest energy by governmental regulations, and particularly by legal and medical supervision of prostitution.

§ 85. **Leprosy** (*Lepra*).—By lepra (*elephantiasis Græcorum*) or leprosy is understood a chronic infectious disease which is caused by the *Bacillus lepræ*, first discovered by Hansen and Neisser, and is characterised anatomically by more or less circumscribed inflammatory growths, particularly in the skin and nerves. According to A. Hansen and Bergmann, lepra is contagious, but not in the ordinary sense of the word, as the attendants upon such patients are only very rarely affected by the disease (Beaven). Bergmann found contagion to be the exciting cause in sixty per cent. of the cases (one hundred and eight). The contagiousness of leprosy cannot be proved by the inoculation of animals, as the bacilli of leprosy can apparently live only in human subjects. In some places, such as the coast of the Baltic Sea, leprosy is chiefly a disease of the poor, who live in the most wretched and filthy surroundings. In the tropics—e. g., in India—Europeans of the better class may acquire the disease from association with the diseased natives, and this is particularly likely to occur if their power of resistance has been diminished by the tropical climate. In my opinion, the endemic extension of the disease can only be explained by the assumption that it is contagious, and it can only be successfully combated by regulations aimed at protection and isolation. Transmission by inheritance can only rarely be proved, the disease in these cases originating for the most part in the family by contact from person to person.

The Lepra Bacilli (Fig. 343), first demonstrated by Armauer Hansen and then by Neisser, are small rods about four to six μ long and almost one μ broad, and are exactly similar to the tubercle bacilli, except that they are somewhat shorter. The lepra bacilli are incapable of spontaneous movement. It is impossible as yet to say whether the bright egg-shaped or round uncoloured spots, which come out when the bacilli are stained, are to be regarded as spores or not. The bacilli are found in the leprous new growths in the skin, nerves, lymph glands, spleen, liver, and testicle, usually in great numbers, partly free in the tissues and partly within the cells in the so-called "lepra cells" (Fig. 343, Neisser, Leloir, etc.). These cells are, some of them, large mononuclear cells, while others are like leucocytes. Wynne found the

bacilli also in spindle-shaped granulation cells, and in rare cases in giant cells, sometimes in great numbers (Boinet, Borrel). According to Unna, the bacilli lie preferably in the lymph spaces of the tissues, and the collections of the bacilli designated as "lepra cells" are artificial products, as he thinks has been proved by his drying method. After decolorising the preparation in nitric acid and distilled water, he dehydrated it, not by alcohol but by heating it over a flame, and then clarified it with xylol. Neisser and Wynne, in particular, have contested this view of Unna's.

The lepra bacilli can be stained in the same manner as the tubercle bacilli, but more easily and rapidly, by using, for instance, solutions like those of Ziehl and Ehrlich. Gram's method is also very useful. Baumgarten's method of staining is as follows: 6 to 7 minutes in a diluted alcoholic solution of fuchsin, then decolourise for one-fourth of a minute in acidified alcohol (nitric acid and alcohol 1:10), wash off in water and stain in aqueous solution of methylene blue. Lustgarten uses the following stain: Stain with aniline water, fuchsin, or gentian violet, and decolourise for a considerable time in one per cent. sub-chloracetate of sodium and wash off thoroughly in water. The artificial cultivation of the bacilli and their successful inoculation upon animals has hitherto been accompanied with difficulties, and though there can be no doubt at all as to the specific pathogenic significance of the bacilli, still a perfectly satisfactory proof of their specific action has not as yet been obtained. Bordoni-Uffreduzzi was the first to cultivate the bacilli obtained from the bone marrow of a man dying of leprosy; he cultivated them at the incubator temperature upon hardened blood serum to which had been added peptone and glycerine, and after several days obtained band-like, whitish-grey colonies with indented borders made up of bacilli of different lengths, generally with a club-shaped enlargement at the ends. Inoculations upon animals were unsuccessful, because the strictly parasitic bacteria rapidly lose their virulence when cultivated outside the body (Bordoni-Uffreduzzi, Baumgarten). Melcher and Ortmann claim to have made successful inoculations upon rabbits. In the human subject also inoculation with the bacilli appears to be very difficult or almost impossible; Arning alone was able to inoculate successfully a condemned criminal by means of particles of tissue from leprous nodes. It is certain that man is the chief sufferer from the leprous poison; but how the disease originates in man and spreads is still uncertain. In the majority of cases the disease appears to spread from person to person by contact—that is, by direct contagion; inheritance plays a small part. Hutchinson's idea that leprosy is spread by eating fish is contested by a great many. According to Hansen, leprosy is not inheritable. In some leprous districts the disease is transmitted by vaccination, and is said to have originated and spread in this way on the Hawaiian Islands (Arning, Tebb). Vaccination should accordingly be performed with great care in leprous districts in order that the leprosy bacilli may not be inoculated with the vaccine lymph. Wahl maintains that leprosy originates preferably in the periphery of the body—that is, in the exposed skin and mucous membrane of the pharynx and larynx, and then very gradually extends to the internal organs by means of the lymph

Fig. 343.—Lepra cells with bacilli. × 700 (Flügge).

channels. According to Thoma, the leprous new formation begins in the inner layers of the skin, in the perivascular spaces, and in the immediate neighbourhood of the smaller blood-vessels, and then penetrates into the subcutaneous fatty tissue, the lymph vessels, and lymph glands. Leprosy attacks almost all the organs of the body, but is localised particularly in the skin and peripheral nerves. Nodules are gradually formed like those in tuberculosis. Large nerves, like the median and ulnar, may swell into strands the size of a finger. In the nerves of a patient with lepra anæsthetica the bacilli are found in the nerve fasciculi, and, besides atrophy and disappearance of the nerve fibres, there is an interstitial sclerosis with sometimes calcareous infiltrations. In the nerve sheaths the leprous disease extends chiefly towards the central nervous system, and in the diseased area, there may be a complete destruction of the nerves, in consequence of which a descending (not leprous) degeneration takes place in the separated portion of the peripheral nerves, involving both the motor and sensory fibres. This explains why every sign of leprous disease is, in certain cases, absent in the peripheral nerves of the area of skin rendered anæsthetic; in such cases the disease is located in parts of the nerves more centrally situated (Dehio, Gerlach). Of the internal organs, the lymph glands, spleen, and liver are most frequently diseased. In the blood usually no bacilli can be demonstrated; but Köbner, Thoma, and Doutrelepont have seen them in the blood and the capillaries of the liver. According to Winiarski, the number of red corpuscles is reduced in the most severe cases to one third, and the percentage of hæmoglobin to three fifths of the normal. The number of leucocytes is in general normal, and the polynuclear leucocytes are much the most numerous. The blood coagulates very quickly (Bake).

Occurrence of Leprosy.—Leprosy has been known since the earliest times, and during the middle ages was distributed through almost all the countries of Europe. At present, in Europe, the disease is found only in Sweden, Norway, Finland, in the Russian Baltic provinces and on the coasts of the Mediterranean and Black Seas, and most frequently on the coasts of Norway and in the south of Spain. Leprosy is widely distributed in different parts of Asia (Asia Minor, Persia, China, India), in America (Central America, north and east coasts), in Africa (Cape Colony), and in Australia.

Symptomatology of Leprosy.—Leprosy usually begins very insidiously, the duration of the incubation, according to Bergmann and others, generally being three to four to five years. This explains the apparent immunity of children to leprosy. A general distinction is made between leprosy of the skin and of the nerves, though, for the most part, they occur in combination. Leprosy of the skin is observed particularly on the face and on the hands and feet, and especially on the extensor aspect of the knee and elbow region. The face shows early a characteristic expression (flattening of the eyebrows, facial paralysis with oblique position of the mouth, inability to close the eyes, etc.). Ulcerative processes soon occur on the fingers. The skin has a characteristic pale, waxy appearance. Hyperæmic spots (lepra rubra) are seen in the skin of different parts of the body, which either disappear,

ıg behind a pigmentation, or gradually grow, forming brownish-
odes the size of a walnut (lepra tuberosa). The nodes, consisting
ially of granulation tissue, may remain stationary for a long time,
y may break down and form ulcers, particularly when subjected
ernal injurious influences. The leprous nodes develop the most
usly upon the face, sometimes singly, but generally in groups,
ıg whole clusters. In consequence of the coalescence of the nodes thick masses result on the eyebrows, the alæ of the nose, the

.—Leprosy of the face (leontiasis lepra
s. lepra leonina), after Münch.

Fig. 345.—Lepra leonina; forty-year-old leper from Cape Colony (Fritsch and Virchow).

ıd chin, so that the physiognomy of such a patient assumes an
sion more or less like that of an animal, and hence the designa-
pra s. facies leonina, or leontiasis (Figs. 344 and 345).

ıe leprosy of the nerves (lepra nervorum anæsthetica, lepra mu-
begins with hyperæsthesia and pain; then anæsthesia usually
s, with trophic disturbances consisting in the formation of white
rown spots and in atrophy of the muscles and bones. Motor
ses are less common. As a result of the anæsthesia, injuries are
ticed and lead to ulcerative processes, in consequence of which
of the fingers and toes may be lost (lepra mutilans). The nerves
d by leprous disease become thickened, particularly between the
fibres and in the neurilemma, as the result of an interstitial
is, sometimes combined with deposits of lime, etc. Lepra nervo-
essentially a degenerative neuritis ascending from the periph-
the centre. This has been briefly described on page 452. In
ases a complex of trophic and sensory disturbances is observed

which resembles syringomyelia. There is no fundamental difference between the two main forms of leprosy, the anæsthetic and the nodular.

Besides the skin and nerves, the disease affects particularly the lymph glands, then the mucous membranes, the eyes, nose, mouth, larynx, and also the liver, spleen, and testicles. Arning has described a miliary leprosy, particularly of the serous membranes, which is similar to miliary tuberculosis. In some of the cases there is probably a mixed infection with tuberculosis. Hansen and Looft are of the opinion that Arning's cases should be regarded as pure tuberculosis, and not as leprosy.

FIG. 346.—Lepra anæsthetica mutilans with loss of the finger-tips; four ulcers of the palm in a man thirty-six years of age, who had lived in the tropics.

Prognosis.—The disease generally terminates after a varying length of time—one to two to five to twenty years—with death either from exhaustion or some intercurrent affection, not infrequently from tetanus. Lepers not uncommonly suffer from tuberculosis at the same time, and die of this (Phillipson).

Diagnosis.—At the beginning of the disease the diagnosis of lepra can present manifold difficulties. For its diagnosis in the early stage the characteristic changes in the face are important. The nodular form may be confused with syphilis, the anæsthetic with syringomyelia. Close questioning of the patient, the histological demonstration of the lepra bacilli, and finally an antisyphilitic course of treatment, may establish the diagnosis in doubtful cases. In syringomyelia, as opposed to lepra anæsthetica, there is usually only a partial disturbance of the sensory sphere—for instance, analgesia and thermo-anæsthesia, with persistence of the tactile and muscular sense (P. A. Morrow). It can be differentiated, furthermore, from syringomyelia and Morvan's disease by the thickenings of the nerves, the pigmentation of the spots, the nodules, and by the presence of the leprosy bacilli.

Treatment of Leprosy.—Though opinions differ as to the contagiousness of lepra, still all authorities are agreed that it is very necessary for general hygienic reasons to isolate and confine the patients in institutions for the purpose. The isolation of lepers should be regulated by international laws. It is particularly important to prevent a spread of the disease from one country to another, which can take place so easily owing to the extensive communication by water that now exists. In localities where leprosy exists the disease is combated best by isolation of the patients and improvement of the social and

hygienic conditions. Energetic measures of protection and isolation have caused a diminution of fifty per cent. in the amount of leprosy in Sweden within twenty years. As yet we do not know any specific remedy for the disease, and consequently the treatment is essentially a symptomatic one, consisting mainly in proper hygiene, warm baths, and the administration of tonics. In febrile attacks antipyretics are given. For the local treatment, Bidenkap, an excellent authority on leprosy, recommends goa powder or chrysarobin, which he applies to the nodes and spots on adhesive plaster. Unna also recommends chrysarobin, and others aristol, salol, creosol, hydroxylamin, europhen, etc. Ribb speaks favourably of chaulmoogra oil, Reissner of gurjun balsam (five drops a day internally, gradually increased to seventy and more; in case of irritation of the stomach or kidneys it should be stopped). The latter is also given in the form of inunctions (three parts gurjun and one part lanolin). Bälz recommends the daily application to the skin of a thick layer of a twenty per cent. salicylic ointment consisting of salicylic acid, lanolin, and vaseline combined with the internal use of gynakadia oil in large doses (fifteen grammes and more a day) and warm baths. In suitable cases surgical treatment has to be adopted. Mitra and others have employed nerve-stretching to advantage in the early stages of anæsthetic leprosy. Creamer scrapes the diseased areas with the sharp spoon. In general, wounds in leprous subjects heal quickly and well; the rapid coagulation of the blood is very striking. Massage of the nodules and thickened nerves is useful in many instances. It is possible to make the nodules and spots disappear in a variety of ways, but we cannot cure the disease. Whether we shall sometime procure a curative serum for leprosy similar to the antidiphtheritic serum the future alone will show.

§ 86. **Actinomycosis.**—By actinomycosis is understood a progressive inflammation and suppuration excited by the ray fungus or actinomyces (Fig. 347), which is observed particularly in cattle, swine, and man, and is transferable by inoculation (Bollinger, Israel, Ponfick, Wolff). Though the actinomyces used to be ranked among the mould fungi (hyphomycetes), Bostroem, in 1885, showed by a special method of cultivation that it belonged to the fission fungi (schizomycetes), and was to be regarded as a variety of cladothrix with branches. Bollinger discovered the actinomyces in cattle, Israel in man, while Ponfick was the first to prove the identity of the actinomycosis of cattle with that of man.

Actinomyces.—In the actinomycotic tumours or abscess-like foci there are found characteristic, yellow, solid granules the size of a grain of hemp. If these granules are crushed and the preparation stained for half an hour in

hot, carbolised fuchsin, or for twenty-four hours in an aqueous solu gentian violet, and then placed for ten to fifteen minutes in a solu iodine in iodide of potassium, then in alcohol, etc., and examined un microscope, these granules will to consist of a characteristic arrangement of branching fil which radiate from a common and possess peculiar club-sha largements (Fig. 347). Similar granules sometimes occur in s tive processes that are not act cotic in nature, and consist of d varieties of fungi (pseudo-act cosis, Paltauff, Illich). The scopic examination of the granu alone show whether the case i real actinomycosis. In every of actinomycetes it is possib certain stage, according to B to distinguish three elements: shaped formations; 2. a c placed network of fungous fi of varying shape and size; coccus-like bodies (spores), whi inate from the fungous filame grow into long rods and br twigs. According to Wolff an the significance of the coc bodies is still obscure. Domee states that the spores, which can examined in potato cultures made at a temperature of 22° to 24° C., o by transverse segmentation of the peripheral filaments, like the arth in the aspergillus, for example. According to Bostroem, who was th make pure cultures of the actinomyces, and according to Moosbrug central network of filaments grows rapidly and luxuriantly, while tl of the glands are to be looked upon as products of degeneration inca further development. This is contested by Partsch. M. Wolff and have cultivated the actinomyces, in the absence of oxygen, upon aga the interior of raw hens' eggs, and have successfully inoculated th cultures upon rabbits by injection into the peritoneal cavity. Afa likewise obtained typical actinomycosis by the injection of pure cul blood serum, agar, and bouillon) into the peritoneal cavity of rabbit troem was unsuccessful in his attempts to inoculate animals from from another animal. The actinomyces colonies, when oxygen is form upon agar peculiar yellowish-white vegetations; but when oxy free access to the colonies there are obtained, according to Bostroe acteristic ochre-coloured forms with a chalk-like covering (Fig. 348 cultures of the actinomyces grow upon blood serum, agar-agar, gl agar, and gelatine, as well as in bouillon; growth upon potato tak more slowly. From what has been said, it follows that the acti

FIG. 347.—Actinomyces (ray fungus) with one branching filament separated from the others (Ponfick).

grows in different ways according to the nature of the nutritive medium and the presence or absence of oxygen. It belongs to the polymorphous bacteria, or rather to the cladothrix species, and may occasionally present itself as a simple rod, the above-mentioned bulbs being absent (Ponfick, Ziegler, etc.).

G. Hesse found in one case of actinomycosis a form of fungus which corresponded neither to the cladothrix described by Bostroem nor to the Wolff-Israel micro-organism of actinomycosis. G. Hesse named his fungus the cladothrix liquefaciens, on account of its great power for liquefying blood serum and gelatine. It is obligate aërobic, germinates from spherules or spores, and grows into long filaments with branches. In the stems of the filaments round spores are developed, which subsequently come away, leaving behind the empty stems.

Outside of the animal body the actinomyces grows by preference upon plants, particularly upon grains of corn.

The actinomyces in a section can best be stained by Gram's method, first with methyl violet, then with Bismarck brown. Weigert gives the section a preliminary stain in orchilla, and then places it in a one-per-cent. aqueous solution of gentian violet, by which the central network of filaments is stained blue and the bulbous periphery ruby red.

Fig. 348.—Pure culture (linear culture) of actinomyces upon agar.

Occurrence of Actinomycosis in Animals.—Actinomycosis is observed particularly in cattle, less often in swine and horses. By far the most frequent site of actinomycosis is in the jaws of cattle. In this situation, according to Bollinger, Ponfick, and Johne, hemispherical, simple, or composite elevations and outgrowths are formed, particularly near the angle of the lower jaw. They cause the skin to become thin, finally break through it, and sprout out like a fungus. They have a greyish-yellow appearance, and are of lardaceous consistency. Upon pressure pus escapes, containing the characteristic yellow granules already mentioned. The latter usually consist of a great number of glandular formations clinging together like corals. The smallest elementary granules are macroscopically scarcely visible, and reveal a tangle of filaments, as before remarked, which terminate at the periphery in club-shaped enlargements (Fig. 347). Microscopically there is usually observed in the centre of the nodule the actinomyces gland, with its characteristic radiate or rather stellate arrangement, surrounded by epithelioid, lymphoid, and giant cells (Fig. 349). The fungus has a chemotaxic action, and becomes encapsulated by leucocytes and young connective-tissue cells (Pawlowski, Maksutoff). The nodules break down later, and for the most part suppurate, thus giving rise to a correspondingly extensive death of tissue. The growth of the tumour is very slow; the number of the nodular-shaped growths con-

stantly increases, and, after coalescing with one another, they extend slowly into the surrounding parts. The tumours consist partly of fibrous connective tissue and partly of granulation tissue, and always contain the characteristic small nodules or foci of suppuration with the fungous glands in the form of the above-mentioned granules. The foci of suppuration are sometimes small and sometimes very extensive. In rare cases spontaneous recovery takes place by cicatricial contraction and calcification. The actinomycetes, which usually grow outside the animal body upon plants, are taken into the system mainly in the vegetable food; but they may also enter through the respiratory tract and an interruption of continuity in the skin. The infection is more apt to occur in cattle living in damp or marshy regions, particularly during or soon after a wet season (Bostroem). The common starting-point of the infection is the cavity of the mouth (jaw, tongue, pharynx), and may be the result of any slight injury to the inside of the mouth produced by stiff pieces of vegetable food, or by a carious tooth, etc. According to Johne and Bostroem in most of the tonsils of healthy swine there are found barley grains which have a fungus on their surface very similar to the actinomyces. In man also, infection is most apt to originate from vegetable material, less often from ingestion of actinomycotic meat or milk. By growing into the blood vessels the primary focus may give rise to metastases in the various organs. Metastases do not usually originate through the lymph channels.

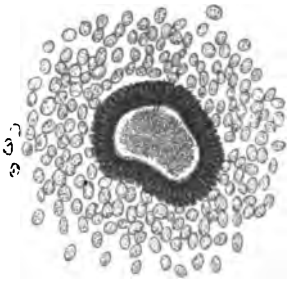

FIG. 349.—Actinomycosis of the tongue with surrounding cellular infiltration, stained with fuchsin. × 200.

Actinomyces Musculorum Suis.—The ray fungus occurring exclusively in the muscles of hogs, the so-called actinomyces musculorum suis, discovered by Duncker in 1884, is not identical with the actinomyces bovis s. hominis. Its radiate form is similar, but its relationship to the actinomyces bovis s. hominis is still obscure.

Actinomycosis in Man.—The occurrence of actinomycosis in man was first carefully studied by J. Israel in 1885. He used observations made by himself, and the thirty-eight cases of the disease which were then to be found in literature. The actinomycosis of man can be divided according to the point of ingress of the infection, into five groups:

1. Cases in which the fungus enters through the oral and pharyngeal cavities forming a focus in carious teeth, in the inferior maxilla, in the submaxillary and submental region, in the neck, in the periosteum of the superior maxilla, or in the vicinity of the cheek.

2. Cases of primary actinomycosis of the respiratory apparatus with localisation in the bronchial mucous membrane and in the parenchyma of the lungs, spreading to the pleura, the peripleural, and paravertebral tissues, or with extension to the abdominal wall, and finally the formation of metastases.

3. Cases of primary actinomycosis in the intestinal tract, partly as a superficial disease of the intestine and partly with extension of the process to the peritonæum and abdominal wall and the formation of metastases.

4. Cases in which the point of entrance is uncertain (respiratory apparatus, pharynx, intestine).

5. Infection in conjunction with an injury of the skin, cutaneous actinomycosis, particularly after injuries of the skin inflicted by foreign bodies such as a splinter of wood, for example. Illich, counting in the

Fig. 350.—Actinomycosis of the right side of the neck, with numerous fistulæ leading to foci of pus, surrounded by indurated tissue. The patient is a thirty-year-old peasant. Recovery.

fifty-four cases which he saw in Albert's clinic, has collected in all four hundred and twenty-one cases of actinomycosis. Of these there were two hundred and eighteen in which the head and neck were affected, sixteen of the tongue, fifty-eight of the lungs, eighty-nine of the abdomen, and eleven of the skin. In twenty-nine cases the point where the infection entered could not be proved with certainty.

Actinomycosis originates in man chiefly from parts of vegetable matter to which the fungus clings. Portions of vegetable matter, especially barley grains, have been repeatedly demonstrated in the actinomycotic foci (Bostroem, Illich, etc.). Infection by eating actinomy-

cotic meat, or by drinking milk, is very questionable. The actinomycosis of man differs from that of cattle by the smaller size of the tumours and by the preponderance of thickening and induration of the tissues. The clinical pictures of actinomycosis in man vary very much according to the primary location of the disease. Sometimes the phlegmonous type of inflammation with a suppurative breaking down preponderates; in other cases the formation of granulations or the induration are most prominent (Fig. 350). The disease may begin as a phlegmonous inflammation about the lower jaw, forming epulis-like tumours, especially when there are carious teeth present, as in a case which I operated upon a short time ago. The process may extend from the mouth or from the jaw to the prevertebral tissue of the cervical and dorsal vertebræ (prevertebral phlegmon), with secondary destruction of the vertebræ. Not infrequently cases are observed which run an acute course, presenting the picture of a very acute or even septic suppuration, for example in the neck, simulating *angina Ludovici;* but this is usually due to a mixed infection, as Partsch and others have insisted, since the actinomyces does not by itself excite suppuration. Occasionally actinomycosis runs a course resembling chronic pyæmia, with the formation of multiple abscesses; or the disease begins in a very insidious manner, as primary actinomycosis of the intestine or lung, with secondary extension to the peritonæum, heart, pleura, and eventually the formation of metastases, etc. Abdominal actinomycosis is characterised by the formation of thick adhesions between the intestines and between the latter and the abdominal wall, and by abscess formation in the retroperitoneal tissues or in the abdominal wall. The metastases may be very numerous, as happened in one case of Sonnenburg's, in which the pleura, lungs, the large abdominal organs, and the skin of the thorax, abdomen, back, and thighs were involved. The primary location of the affection could not be determined.

In a pure actinomycosis without any mixed infection, such as with pus cocci, the lymph glands are usually not affected, and the metastatic infection takes place not through the lymph vessels but through the general circulation. Bollinger saw one case of primary actinomycosis of the brain in a twenty-six-year-old woman with bad teeth, who had for a long time drunk raw goats' and cows' milk as well as eaten raw meat. The rather rare cases of isolated cutaneous actinomycosis sometimes take the form of cutaneous ulcers, and sometimes of nodular eruptions like tubercular lupus (Leser).

Diagnosis of Actinomycosis.—The above-mentioned characteristic yellow granules which are found in the pus or in the granulation tis-

sue, as well as the microscopic demonstration of the fungus, are of great importance in making the diagnosis.

Prognosis of Actinomycosis.—The prognosis depends mainly upon the situation of the disease, and is favourable in those cases in which the diseased parts are accessible to surgical treatment—for example, when they are located in the region of the cheeks, the jaw, the cavity of the mouth, the neck, etc. As Schlange has correctly remarked, actinomycosis has a pronounced tendency to get well spontaneously—a fact which is particularly noticeable when, in actinomycosis of the neck or cheek, the fungi have penetrated beneath the skin and then are finally cast off as foreign bodies. The great majority of all cases of actinomycosis which are accessible to surgical treatment can be permanently cured. The prognosis of actinomycosis of the internal organs is very unfavourable.

Treatment of Actinomycosis.—The treatment of actinomycosis is wholly surgical; it consists in extirpation or in incision followed by energetic scraping out and disinfection of all accessible foci. In very diffuse actinomycosis of the skin antiparasitic remedies may be used, such as chrysarobin, ichthyol, etc. Parenchymatous injections of the iodide of potassium or sodium into the actinomycotic areas are useful in suitable cases (one to two to five hypodermic syringefuls of a one-per-cent. solution at intervals of several days). This may be combined with the internal administration of potassium iodide. The actinomycosis which is accessible to surgical, that is, to operative treatment—for example, actinomycosis of the cheeks, tongue, jaw, the oral cavity, the neck, etc.—always has a favourable prognosis, as remarked before, and a permanent cure is generally obtained, provided only the actinomycotic focus is thoroughly removed. I operated on a case of actinomycosis in a young milkmaid involving almost the entire lower jaw. The loosened teeth subsequently became perfectly firm, and the restoration of the lower jaw was very satisfactory. In case of infection of the internal organs, with diffuse foci located in the thoracic or peritoneal cavities, all treatment is usually unavailing, and even the recognition of the disease may present the greatest difficulties. In cases not suitable for operation, preparations of iodine (iodide of potassium and of sodium) should be tried; the course of the disease has been favourably influenced by these in a number of cases. Tuberculin has also been employed with varying results.

CHAPTER II.

INJURIES AND SURGICAL DISEASES OF THE SOFT PARTS.

(SKIN, CELLULAR TISSUE, MUCOUS MEMBRANES, BLOOD-VESSELS, LYMPHATIC SYSTEM, NERVES, MUSCLES, TENDONS, TENDON SHEATHS, BURSÆ.)

Wounds of the soft parts (incised wounds, punctured wounds [phlebotomy], contused and lacerated wounds).—Treatment of wounds of the soft parts (hæmostasis, tenorrhaphy, neurorrhaphy [muscle- and nerve-regeneration], suture of a wound, dressing).—Treatment of the conditions following severe loss of blood (transfusion, salt infusion).—Burns; sunstroke; injuries from lightning; congelation; gunshot wounds of soft parts; of bones and joints.—Subcutaneous injuries of soft parts (contusion; subcutaneous rupture of tissue; muscular hernia; dislocation of tendons and nerves).—Inflammations and diseases of the soft parts (skin, cellular tissue, mucous membranes, arteries, veins, lymphatic system, nerves, muscles, tendon sheaths, bursæ).—Gangrene of the soft parts.

§ 87. **Wounds of Soft Parts.**—Of the various kinds of wounds, the simple incised wounds are the ones which present most clearly for the beginner the symptomatology of wounds of soft parts, and hence we shall begin with them.

Symptomatology of Wounds, particularly Incised Wounds.—The chief symptoms revealed by every wound are pain, hæmorrhage, and gaping of the edges.

Wound Pain.—The degree of pain from a wound varies with the peculiarities of the individual, the portion of the body affected, and the nature of the injury. Every one knows that the susceptibility to pain manifested by different people is very variable. As regards the location of the injury, wounds of the fingers, lips, nose, the external genitals, and bone are particularly painful. The division of a sensory or mixed peripheral nerve is accompanied by overpowering pain, while division of the white matter of the brain, in spite of the numerous nerve fibres it contains, causes no pain to speak of. If the division of the tissues is done rapidly with a sharp instrument, the sensation of pain is less than when it is done slowly and with blunt instruments. Consequently it is best, particularly in patients who are not chloroformed, to operate with a sharp knife, and to divide the skin, with its rich supply of nerves, rapidly by a single stroke. In gun-shot wounds the tissues are divided so quickly that the pain is often slight.

The subjective feeling of pain accompanying the injury is less important for the physician and has less bearing upon the treatment than the other objective, perceptible symptoms—the hæmorrhage and the gaping of the margins of the wound.

Gaping of the Wound.—The gaping of the wound—that is, the separation of the divided soft parts—is caused by the tension and elasticity of the tissues and by the contractility of the muscular elements. Hence it is natural for the skin, fascia, tendons, muscles, vessels, nerves, etc., after being divided, particularly if in a transverse direction, to be pulled asunder.

Hæmorrhage.—The hæmorrhage (extravasation) is the most important manifestation in the wound. In every division of tissue, lymph, in addition to blood, is poured out of the divided lymph spaces and lymph vessels; but the outflow of lymph is arrested partly by coagulation and partly by even a very slight resistance in the wound, as the amount of pressure in the lymphatic vessels is very small, being no greater than in the surrounding tissues. Besides the blood and the lymph, when injuries involve such structures as glands, joints, etc., there may be an escape of the fluid peculiar to these organs, such as glandular secretion, synovia, etc.

We are mainly interested in the extravasation of blood from the vessels—hæmorrhage. This is either arterial, venous, or capillary—i.e., parenchymatous.

Arterial Hæmorrhage.—Arterial hæmorrhage is characterised by bright-red blood which spurts in a smaller or larger stream from the injured vessel. When there is danger of asphyxia, the colour of the arterial blood is not bright red but dark red, like venous blood; indeed, in bad cases of asphyxia, shortly before death, the blood has a remarkably dark-red or even an actually black colour. Under such conditions, as a result of the threatening cardiac paralysis, the blood pressure in the arterial system is so lowered that the blood does not spurt forth in jets, but flows more continuously or suddenly ceases entirely, as we have described, for example, on page 30, in case of threatened death from chloroform. The bleeding from small arteries usually ceases of its own accord from retraction and contraction of the arterial walls and from the pressure of the surrounding tissues. In larger arteries the bleeding does not stop of itself, and the injured person bleeds to death unless the hæmorrhage is arrested by artificial means. The amount of the hæmorrhage depends, of course, when the artery is entirely divided, upon the size of the vessel, and, when partially divided, upon the size of the opening in the wall of the vessel. Longitudinal wounds of an artery are not so dangerous as transverse

ones, as the latter gape more, and consequently render spontaneous arrest of the hæmorrhage difficult. A transverse division of a large artery, such as the common carotid, the brachial, or femoral, will be followed by death from loss of blood in a short time, except in the case of punctured wounds, or in contused and lacerated wounds. In contused and lacerated wounds, even in those resulting from tearing away an extremity, the hæmorrhage may be very slight. The contused and lacerated vessels are crushed, and, in the case of arteries, the media and intima are rolled inwards, while the adventitia is likewise twisted or pressed together; hence the bleeding is only slight. But in all contused wounds secondary hæmorrhage very frequently occurs when the contused portion of the vessel or the thrombus separates. Secondary hæmorrhage also readily results from punctured wounds of arteries which have been closed by a temporary contraction of the elastic arterial wall or by a blood-clot.

Hæmorrhage from the Veins.—In hæmorrhage from the veins the dark-red blood flows out more continuously, and when a vein is completely divided it flows most freely from the peripheral end. In large veins, when the valves are insufficient, or when in the neighbourhood of the injury large branches open into the main vein, the blood flows backwards out of the central end. Under these conditions hæmorrhage takes place from both ends of the divided vein. Hæmorrhage from the large veins in the neighbourhood of the trunk is particularly dangerous to life if aid is not at hand; the dark-red blood usually wells forth in great quantities. But patients have occasionally bled to death even from varicose veins of the leg. The reasons for such severe hæmorrhage are that the return flow of venous blood from the dilated veins of the leg is rendered difficult by the dependent position of the veins and by the partial obliteration of the venous channels by previous inflammatory thrombi, and that the patients often have absolutely no idea of how to help themselves. Under such circumstances, instead of elevating the leg and compressing the wound with the finger, they use the strangest kind of methods for arresting hæmorrhage.

Hæmorrhage from Capillaries.—The hæmorrhage from the capillaries and small veins usually ceases spontaneously in consequence of the retraction of their walls, and particularly because of the coagulation of the blood (see page 296). It is well known that the blood which leaves the vascular passage coagulates, and a blood-clot, a so-called thrombus, forms in the wound in the vessel (see page 296), which not only shuts off the communication of the vessel with the exterior, but also extends for some distance into its lumen. In this way the

hæmorrhage ceases, provided the blood-clot is not washed away by the blood current. The thrombosis takes place the more rapidly and certainly the less the blood pressure is in the vessels, particularly the capillaries and small veins. But the spontaneous closure by a thrombus of a wound in an artery or large vein which is adherent to the surrounding parts is difficult or even impossible.

The Results of a Great Loss of Blood.—After a great loss of blood there follows a falling off of the arterial pressure and a cardiac weakness whereby thrombus formation is facilitated. A severe hæmorrhage is thus, in itself, more or less hæmostatic in its effects. In the same way hæmorrhage is much diminished by transitory heart weakness during a fainting spell, even when due to psychic influences. As a result of severe hæmorrhage the blood itself is changed. It becomes richer in colourless corpuscles, which flow out of the vessels of the smallest calibre where they had accumulated, and the lymph, with the lymph corpuscles, also streams with greater rapidity and in greater quantities into the depleted vascular system. Under these circumstances the coagulability of the blood increases, and this again facilitates the spontaneous arrest of hæmorrhage. If a dog is bled to death by repeated phlebotomies, the blood last taken from the animal will often coagulate almost immediately.

Further Manifestations Following Severe Loss of Blood.—The further symptoms following severe loss of blood consist in pallor and coldness of the skin particularly that of the face and the extremities, in great weakness, spots before the eyes, ringing in the ears, nausea, vomiting, a feeling of anxiety, vertigo, fainting attacks, etc. The certain precursors of rapidly approaching death from loss of blood are severe dyspnœa, stoppage of the glandular secretions, loss of consciousness, dilatation of the pupils, involuntary evacuation of urine and fæces, convulsions which are excited by sensory irritation, such as a needle-prick, etc. The high grade of dyspnœa and the convulsions preceding death from hæmorrhage are a result of the rapid impoverishment of the brain in oxygen, such as occurs in strangulation (Rosenthal). The same set of symptoms, it is well known, make their appearance in the Kussmaul-Tenner's experiment, when by occlusion of the carotid and vertebral arteries an acute cerebral anæmia is excited, or when the return flow of the venous blood is suddenly interrupted.

Powers of Withstanding Loss of Blood.—The power of withstanding loss of blood appears, to a certain extent, to be subject to individual variations. After severe loss of blood every surgeon has seen in a relatively short time—two to three days—threatening symptoms vanish in cases where he expected certain death; and again, on the

other hand, some patients go into collapse after the loss of very little blood. Very young children may be endangered by an insignificant hæmorrhage, and weakly children a year old have died after a loss of only two hundred and fifty grammes of blood. In strong adults, who are otherwise healthy, the loss of half the total amount of blood is sure to be fatal. Women appear to stand loss of blood better than men. The formation of new blood seems to take place more easily and rapidly in them on account of the periodic replacement of the blood lost in every menstruation (Landois). Fat people and old and weak individuals are very susceptible to loss of blood. The more rapidly the hæmorrhage takes place the more dangerous it is.

Death from Hæmorrhage observed in Experiments on Animals.—In general, the facts which we have ascertained by bleeding dogs to death experimentally are also applicable to man. As much as a quarter of their total normal quantity of blood has been withdrawn from dogs by phlebotomy without causing the blood pressure in the arteries to sink permanently. During the phlebotomy the arterial pressure, of course, falls off rapidly, and the pulse becomes small. But very soon, even in a few minutes, the pulse again becomes stronger, the blood pressure rises, not because the contents of the vascular system have correspondingly increased, but simply for the reason that the arteries contract in consequence of the irritation of the vasomotor centre in the medulla oblongata produced by the anæmia, and thus accommodate themselves to the diminished amount of blood they contain (Landois). The anæmia caused by the loss of blood acts as a stimulant to the centre of the vasomotor nerves. It overcomes the transitory fall in pressure following the loss of a certain quantity of blood which is within the above-mentioned limit. The rapidity with which the blood flows and the frequency of the cardiac contractions remain the same as before the hæmorrhage. But if more than a quarter of its contents is withdrawn from the vascular system—a third, for example—the arterial pressure does not again rise, but remains lowered, the rapidity of the current decreases, and the contraction of the heart becomes slower in consequence of the incomplete filling of the ventricle. But as the vagus centre receives less stimulation in consequence of the diminished arterial pressure, the frequency of the pulse is usually accelerated (Cohnheim). At the same time, a change takes place in the composition of the blood, the water it contains being increased by absorption of the parenchymatous liquids and by the accelerated flow of the lymph from the thoracic duct. As a result of the lowered blood pressure the contents of the capillaries do not transude any longer from within outwards, but the reverse condition prevails: there ensues a diffusion and absorption from without inwards (Cohnheim).

In man, a loss of blood amounting to about one half of the total normal quantity always proves fatal; but even a moderate loss, amounting to a quarter of the total quantity, would give rise to serious dangers for the organism in a short time, unless the blood lost were replaced

by a corresponding regeneration of blood. The hæmorrhages which are difficult to stop and occur in bleeders, as they are called (see pages 62–65), are especially dangerous.

Regeneration of the Blood after a Hæmorrhage.—If the bleeding does not go on to death the blood is restored by absorption from the tissues or from the food taken in, the first to be absorbed being the serum sanguinis, with the dissolved salts, and then the albumen. A longer time is required to form new red blood-corpuscles. The great thirst following profuse hæmorrhage is characteristic. The patients eagerly drink great quantities of water. The regenerated blood is at first abnormally watery (hydræmic) and poor in cells (oligocythæmia, hypoglobulous). As a result of the greater flow of lymph into the blood the number of the white blood-corpuscles is greatly increased, and then their amount falls off; the red blood-corpuscles again attain their usual number, and the composition of the blood gradually returns to the normal. We do not as yet know certainly how the restoration of the red blood-corpuscles takes place. The most generally accepted view is that colourless corpuscles are being constantly formed in the lymph glands, in the spleen, the bone marrow, and in the liver, and a certain number of these colourless corpuscles change into the red disks (Neumann, Erb). After moderate losses of blood in animals, Buntzen saw the volume of the blood restored in a few hours, and when the loss was severe, within twenty-four to forty-eight hours. The red blood-corpuscles, after hæmorrhages amounting to from 1.1 to 4.4 per cent. of the body weight, were again complete after the lapse of seven to thirty-four days. The beginning of the regeneration was proved to take place after forty-eight hours.

Entrance of Air into the Veins.—Among the dangers which may follow an injury to a vein, particular mention should be made of the entrance of air into the vein, a matter which we discussed on page 65.

Of the other symptoms caused by wounds, those are of especial importance which indicate division of the muscles, tendons, and nerves, or the opening of a joint or a cavity of the body. I shall refer to the latter complications under Injuries of Joints, and in the Text-Book on Regional Surgery (injuries of the cranial cavity, thorax, and abdomen, and of the separate joints).

Division of Muscles and Tendons.—The symptoms which indicate a division of muscles and tendons are very simple; they consist in disturbance of the function of the affected muscle, and, in addition, the divided muscles and tendons can usually be seen at once when the incised wound is carefully inspected.

Division of the Nerves.—The symptoms following division of the peripheral nerves (we omit incomplete divisions, contusions, and punctures of nerves) consist likewise in a corresponding functional disturbance of the affected peripheral nerve—in other words, in sensory and motor disturbances.

Degeneration of Nerve Fibres cut off from their Centres.—Nerve fibr cut off from their connection with the central nervous system after time lose their excitability; they undergo a fatty, granular degener tion, which involves the entire separated portion of the nerve down its finest peripheral branches (Müller, Waller). The sensory fibre according to Waller, degenerate not in the peripheral but in the cen tral portion when the posterior root is cut above the spinal ganglion The spinal ganglion consequently plays the same part in the preserva tion of the sensory fibres that the spinal cord does for the motor. The paralytic degeneration probably occurs simultaneously in the whole length of the peripheral portion, not spreading from the point of sec tion towards the periphery, nor beginning, as Schiff describes it, in the peripheral network. The contents of the nerve finally disappear com pletely, and probably the empty neurilemma also. The connective tissue of the nerves is the seat of an inflammatory, nuclear prolifera tion. There is still a division of opinion as to whether or not the degeneration likewise involves the peripheral end organs, such as the tactile corpuscles, the rods of the retina, the terminations of the ol factory nerves, etc. Recently F. Krause has carefully studied the ascending and descending degeneration of divided nerves, and he state that all the sensory fibres in the peripheral segment of the nerve which are connected with a trophic centre in the periphery, such as Meissner's tactile corpuscles, remain intact, but the central segment of the nerve undergoes degeneration. On the other hand, all the motor nerve fibres and the sensory fibres of the bones, periosteum, joints muscles, tendons, and the sensory fibres terminating free in the skin persist in the central nerve segment and degenerate in the peripheral portion of the nerve. At the same time that these degenerative pro cesses are taking place in the nerves, the muscles atrophy and in part undergo fatty degeneration.

The disturbances of sensation after division of nerves are not so pronounced as the motor-paralytic manifestations. If, for example, a mixed nerve in the extremities—such as the median or ulnar—is di vided, the manifestations of motor paralysis are always exhibited in a typical manner, while the sensory paralysis may be very slight or almost completely absent, because the collateral anastomoses of the neighbour ing uninjured nerves take up vicariously the conduction of the sensory impulses. There is an intimate anastomosis between the finer nerve branches in the skin, particularly upon the fingers, and in the face The individual perceptive senses appear to behave differently afte injuries. It sometimes happens that all the senses—that is, the tactil temperature, and pain sense—are lost after division of a nerve, or the

are more or less retained; in still other cases only the tactile sense persists while the pain and temperature senses are suspended. Immediately after the injury the disturbances of sensibility are most pronounced, and after four to six days the manifestations of sensory paralysis improve without its necessarily following that a regeneration of the nerve has occurred at the injured point. Indeed, the disturbance of sensibility may disappear more or less completely, though, in fact, no union has taken place between the divided ends of the nerve. The collateral paths gradually take on more and more activity, or new-formed nerve-fibres grow from the uninjured, collateral nerves into the anæsthetic, cutaneous district.

As regards the motor disturbances, the muscles supplied by any particular motor or mixed nerve are always paralysed after division of this nerve. The position of the hand—for instance, after division of the musculo-spiral, median, or ulnar nerve, is always a typical one (see Regional Surgery). Variations from the general rule of course may occur when there are anomalies in innervation. There is observed, however, after nerve division, especially in the subsequent course of the case, more or less substitution in the sense that other muscles, supplied by an uninjured nerve, perform singly or in groups the duties of the paralysed muscles. According to Létiévant, these substitutions may act so perfectly, when occurring between the ulnar and median nerves, for example, that it is possible on superficial examination to overlook an actually existing paralysis of the parts supplied by the divided nerve. Küster and Falkenheim have described analogous cases. If, after division of a mixed or motor nerve, paralysis is partially or entirely absent, the cause is to be ascribed, according to observations made upon such cases by Kraussold, Spillman, and others, to anomalies of innervation or to the persistence of undivided collateral nerve filaments which connect the central and peripheral stump of the divided nerve. The further towards the centre a motor or, rather, mixed nerve is divided, so much the more extensive are, of course, the symptoms of motor paralysis.

Of the other symptoms which follow division of peripheral nerves I should briefly mention the following: Very frequently, indeed almost always, the patients after division of a nerve complain of a marked sensation of cold in the paralysed district. Hutchinson states that the difference in temperature amounts to from 2.2° to 5° C. (4° to 9° F.). Kraussold and Rohden found that the temperature in the paralysed parts after division of the ulnar nerve was lowered as much as 6° to 9.8° C. (10.8° to 17° F.). In rare cases the temperature in the paralysed parts has been observed to be elevated 2° to 5° C. (3.6° to

9° F.) (Haym). Other manifestations are a burning, prickling pain, formication, an increase in the secretion of sweat or a remarkable dryness of the involved area of skin, and, finally, cutaneous affections such as herpes zoster, eczema, pemphigus, ecthyma pustules, disturbances in the nutrition of the skin, such as the formation of eschars, ulceration, or gangrene, especially on the finger-tips. The skin is œdematous, bluish red, or abnormally pale. In the periosteum and bones inflammatory and trophic disturbances are also observed. In the joints there are serious effusions taking the form of chronic hydrarthrosis or subacute articular rheumatism, adhesive joint inflammations, now and then terminating in a stiff joint—anchylosis. The neuroparalytic (neuropathic) joint disturbances, resembling a subacute articular rheumatism, lead to a painful swelling of the joint, and finally to distention and subluxation of the articular surfaces, to marked atrophy of the bone, and to destruction of the whole joint. All of the last-mentioned changes in the bones and joints occur only as the final results following an unhealed division of a nerve. After the paralysis has lasted some time a progressive atrophy of the portion of the body in question takes place not only in the muscles and the soft parts but also in the bones. The electrical excitability of the divided nerves and muscles decreases by degrees, and finally is lost entirely.

I. **Punctured Wounds.**—Punctured, contused, and lacerated wounds present many peculiarities, and it is therefore necessary to study them somewhat more in detail.

Punctured wounds are produced by sharp or blunt-pointed instruments, such as swords, daggers, knives, needles, splinters of glass or wood, etc. Arrow wounds of the Indians, for example, are described in § 82. Punctured wounds belong, in the majority of cases, to simple wounds, and heal comparatively quickly if the injury does not involve deeply lying parts, such as vessels, nerves, joints, or the large cavities of the body with their contents, including the cranial cavity, the pleural or peritoneal cavities. Sharp-pointed instruments in general produce punctured wounds with smooth borders, while blunt-pointed objects are more apt to contuse the borders of the wound. Punctured wounds, as a general thing, correspond in shape to the instrument by which the wound was produced—a fact which is of especial importance in medical jurisprudence.

In a great number of punctured wounds the depth of the wound is disproportionately great in comparison to its length and width, and the nature of the injury is not so apparent as in incised wounds. If large arteries or veins have been injured, the hæmorrhage which appears externally may be relatively slight. If a large artery is punctured, at

the moment of the injury a great bright-red stream of blood spurts out; but after removal of the instrument only a little blood trickles from the wound, because the puncture in the artery has been closed by the elasticity of the arterial wall. Should the hæmorrhage continue from the artery, it does not appear externally, but takes place into the tissues surrounding the vessel, because the soft parts divided by the puncture fall together again, and do not permit the blood to escape to the surface of the body. Under such conditions a large blood tumour forms, a so-called traumatic aneurysm, in contradistinction to the true aneurysm, which is a more gradually developing, sacculated, or spindle-shaped dilatation of an artery. In the traumatic aneurysm there is heard, upon auscultation with the stethoscope over the blood tumour and so over the point of injury, a systolic *bruit* or murmur isochronous with the pulse, caused by the outflow of the blood through the opening in the artery into the surrounding tissues. This systolic murmur, following a puncture in an artery, ceases immediately when the artery involved is compressed above the point of injury or when the hole in the vessel becomes closed by a thrombus. No sound is heard, however, when the artery is cut completely across. These murmurs are of great diagnostic importance.

Punctured Wounds involving a Vein and Artery.—If an artery and a vein are injured simultaneously by a puncture (as may occur, for example, in phlebotomy when the point of the knife is stuck too deeply into the median basilic vein and penetrates the brachial artery lying under the vein), there may result a permanent communication between the artery and the vein; a sac is formed

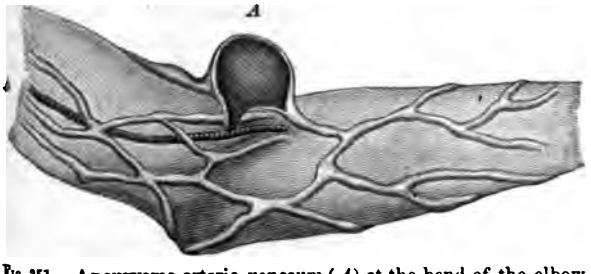

Fig. 351.—Aneurysma arterio-venosum (*A*) at the bend of the elbow resulting from venesection; *b*, arteria brachialis (Bell). The sac *A* of the aneurism is laid open (Froriep).

Fig. 352.—Aneurysma arterio-venosum (Busch).

(Figs. 351, 352), into which flows the blood of the artery as well as that of the vein. This condition is called aneurismal varix, or varicose aneurism, or, better still, arterio-venous aneurism.

Technique of Phlebotomy, or Venesection.—This is perhaps the best place for briefly considering blood-letting. Venesection, or phlebotomy, formerly much used for all sorts of diseases, is at present almost never done in surgical practice. Phlebotomy is performed almost exclusively on the veins of the elbow, particularly the median basilic, which is generally the best developed (Fig. 353). It is to be noted that the medio-basilic vein crosses the brachial artery, and at this point is only separated from it by the very thin aponeurosis of the biceps muscle; consequently before the operation it is best to feel for the pulsation of the artery, and to open the vein either above or below the point where they cross. In order to avoid subsequent neuralgia the middle and external cutaneous nerves (Fig. 353) should not be injured. Phlebotomy is performed in the following manner: In the first place, the middle of the (upper) arm is encircled by a bandage, or piece of folded cloth, to produce venous stasis and distention of the vein. The tourniquet should not be applied so tightly as to close the artery; the radial pulse must therefore persist. The arm should hang down, to permit a more complete filling of the vein. The vein is best opened with a pointed scalpel after the field of operation has been carefully scrubbed with soap, shaved, and disinfected. If the outflow of blood is not free it can be made to become so by muscular contractions—for instance, by opening and closing the hand. When a sufficient amount of blood has escaped, the wound is closed by the finger, the tourniquet removed, and the small wound covered with an antiseptic dressing, which exerts a slight pressure. This small operation must, of course, be carried out with a careful observance of antiseptic precautions. In the preantiseptic days suppurative venous thrombosis and death from pyæmia were of relatively frequent occurrence.

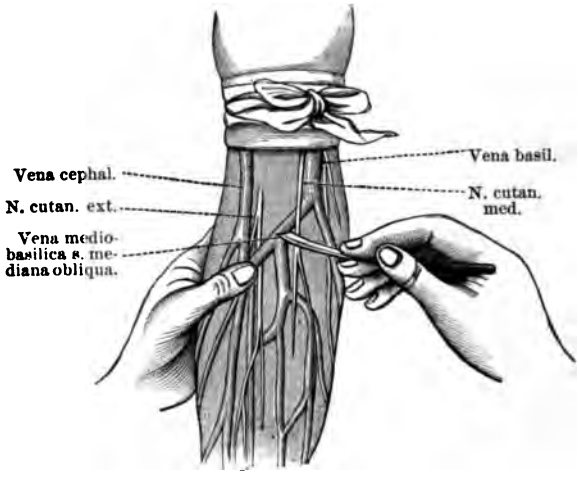

FIG. 353.—Venesection (right elbow).

Spontaneous healing of a Punctured Wound in a Vessel.—A puncture in an artery can heal spontaneously if there is not too much gaping of the wound. The small opening is closed by the contraction of the elastic walls of the vessel or by a blood-clot. In the case of larger arteries the formation of a blood-clot closing the hole is rendered difficult in consequence of the high intra-arterial pressure. In smaller arteries, where the pressure is not too great, the coagulum is more

likely to remain in position, and the clot extending into the lumen of the vessel may receive fresh layers from the blood flowing by it, and thus there can result a complete closure of this portion of the vessel —in other words, a completely occluding arterial thrombus. But in all cases where spontaneous healing of a puncture in a vessel is accomplished by a clot, there is the danger that the latter may be swept away at any time should there be considerable intra-arterial pressure, and thus a renewal of the bleeding will take place—a so-called secondary hæmorrhage. Punctured wounds of veins heal spontaneously very readily by becoming closed with a thrombus. The blood coagulates easily here on account of the slight intravenous pressure, and the walls of the veins collapse if not prevented from doing so by natural adhesions to the surrounding parts, such as fascia or bones. After veins have been wounded there result extensive venous thrombi, which, especially in the preantiseptic days of surgery, used to be greatly dreaded, as they often underwent suppuration with subsequent general septic poisoning (pyæmia).

Punctured Injuries of Nerves.—Punctured injuries of nerves may either completely or, more often, partially divide them, and are of special practical import. The extent of the paralysis caused by the injury to the nerve depends upon the number of the nerve fibres which have been divided. If the nerve is not cut entirely through, spontaneous healing usually follows without surgical interference, in case the nerve was at the same time not too much contused. In one instance I saw an incurable paralysis of the ulnar nerve follow a punctured wound of the nerve made by a steel pen filled with ink. The nerve was months afterwards coloured black throughout a large part of its extent. Small foreign bodies, such as needle points, bits of glass, etc., may become encapsulated, and they often give rise in sensory or in mixed nerves to very painful cicatrices and cicatricial tumours (neuromata) or to epileptiform attacks. Before the attack begins the patient usually feels a pain in the cicatrix.

Punctured Wounds of Joints and of the Large Cavities of the Body.—During the first few hours or days after the injury there may often be doubt as to whether a joint or a large cavity of the body, with one of its vitally important organs, has been injured. It is true that punctured wounds entering joints or cavities of the body not infrequently heal up without treatment; but in other cases it becomes evident, after the lapse of a few days, that the punctured wound has given rise to suppuration in the joint, or that some important internal organ has perhaps received such injuries as to cause death.

Traumatic Emphysema.—In conclusion, mention should be made the occurrence of air in the neighbourhood of punctured wounds—traumatic emphysema, as it is called. If, after punctured wounds, *air* collects to a greater or less extent in and under the skin, there will be felt a slight crepitation in the affected areas. The air can be easily removed by pressing and kneading with the fingers. Traumatic emphysema, or the collection of air, especially in the subcutaneous cellular tissue, may be due to an injury to an organ which contains air, such as the lung or trachea. After injuries of the lung the air may spread beneath the skin over the entire body wherever it meets with the least resistance. Air can also be sucked into the wound from without by aspiration. It is well known that there also occasionally arises a so-called "spontaneous" or primary emphysema after subcutaneous extravasations of blood, especially in fractures (Velpeau). According to H. Fischer, this is due to gases from the blood which are set free by the action of an acid, such as the lactic acid which is present in the contused tissues. This so-called spontaneous emphysema can be produced experimentally in animals by exciting in them an extensive extravasation of blood, and then injecting lactic acid into the latter. In one case which Fischer observed the gas consisted almost entirely of carbonic acid. A careful distinction must be made between the various kinds of emphysema hitherto described and the emphysema of decomposition—that is, the collection of the gases of decomposition in the rapidly spreading putrefactive processes which may take place in severe open wounds as a concomitant symptom of very advanced sepsis, and in the so-called malignant œdema, etc. (pages 339–341).

Further Course of Punctured Wounds.—The further course of punctured wounds can be inferred from what has already been said; it depends essentially upon whether important, deeply situated organs such as arteries, nerves, joints, the thoracic, peritoneal or cranial cavities, with their organs, are injured or not, and whether excitants of inflammation in the form of bacteria are introduced into the wound by the instrument inflicting the injury, and, finally, whether a foreign body, such as the point of an instrument, is left sticking in the depths of the wound. If all the complications which have been mentioned are absent, then punctured wounds heal very rapidly like simple wounds. If substances which excite inflammation or bacteria have been carried into the wound by the instrument, or if a foreign body has been left in the wound and the wound has not received antiseptic treatment, suppuration, abscesses, or a deep and spreading cellulitis may follow, and possibly death from pyæmia and sepsis. After a simple needle-prick of the finger septic cellulitis has been repeatedly observed which

ran a fatal course, and with such rapidity that, although a disarticulation of the humerus was performed on the fifth or sixth day, it was impossible to save the life of the patient. Not infrequently punctured injuries heal superficially without suppuration, and yet in their depths inflammation and suppuration take place, especially if a non-aseptic body be present.

Behaviour of Foreign Bodies in a Wound.—Among the foreign bodies which may be left behind in a punctured wound are broken-off needle points or entire needles, knife points, sword points, splinters of glass or wood, etc. Knife and sword points are particularly apt to break off after penetrating bones. Not infrequently the foreign bodies remaining in the wound heal in without reaction when they were more or less aseptic, i. e., clean. Needles have been found embedded in the brain and heart (see Regional Surgery). E. Simon, while conducting an autopsy upon an adult, found a pin healed up in the brain which had probably been introduced through the open fontanelle during the first year of his life. Huppert, while making the post-mortem examination upon an idiot, found a needle in the heart which extended free into the left ventricle five to six lines. The needle was enclosed by a membrane covered with endothelium, and had caused no particular symptoms during life. It had been in the heart about five years. Foreign bodies frequently leave their original location; they wander—i. e., they are pushed on by muscular contraction and by the elasticity of the tissues. They may get into internal organs and cause serious trouble, or after weeks, months, or years they may reach the skin at some point, not infrequently causing an abscess, from which they are then extracted. Billroth removed a knitting-needle almost a foot long from the inguinal region of a thirty-year-old idiot, whither it had probably come from the vagina or rectum. Needles which have been swallowed also pass, without causing trouble, through the walls of the stomach and intestine and may get into the urinary bladder, where they give rise to a vesical calculus by deposition of urates upon the needle. In another case, a pin which had been swallowed lodged in the œsophagus and killed the patient by puncturing the aorta. There are a great number of recorded cases illustrating the healing in and wandering about of foreign bodies, and I could add to the list a considerable number of surprising ones. For demonstrating the presence of foreign bodies the Roentgen rays may be employed (see Surgery of the Bones, Gun-shot Injuries, § 124).

The healing in of foreign bodies is also discussed in § 61.

II. **Contused Wounds.**—The contused wounds belong to the complicated wounds; the tissues are crushed by the force applied by a blunt object. Not infrequently they are a part of very extensive injuries in which the soft parts and bones have been reduced to a pulp. All the various kinds of wounds produced by blunt instruments belong to the class of contused wounds; such, for instance, are the wounds produced by "run-over" accidents, by the kick of a horse, etc., also the numerous machinery and railroad injuries so very common in

modern industries and transportation. Gunshot wounds are, in the main, contused and lacerated wounds, and will be discussed more fully under Gunshot Fractures (§ 124). Wounds caused by bites likewise belong to contused wounds. Bites of rabid animals and poisonous snakes are described in §§ 80 and 81.

Appearance of Contused Wounds.—The appearance of contused wounds differs very essentially from that of incised wounds. The borders of the wound are not smooth and of normal appearance, but, as a result of the bruising, are infiltrated with blood, bluish-black in colour, swollen, and often irregular in shape. The bloody infiltration of the tissues varies with the amount of force to which they have been subjected; not infrequently the extravasated blood spreads to a great distance in the parts around the wound. Occasionally the borders of the wound, or the more deeply lying parts, are so crushed that they subsequently perish. When scratched with a knife no blood flows out, and the patient has lost all sensation in the affected part. The appearance of skin which has been badly crushed varies according to the amount of blood it contains: it may be red shading off into bluish or dark blue, violet, or white, and corpse-like and cold to the touch. Occasionally completely crushed skin looks apparently normal and yet it is dead. Not infrequently the gangrene of the skin does not become evident till several days after the injury. In severe cases of contused wounds the borders of the wound and the injured tissues in general are torn into shreds, the skin is more or less extensively stripped from the underlying parts, the fascia, tendons, nerves, and vessels are mangled; in short, the soft parts are crushed to a pulp and the bones broken into numerous fragments, etc. But in such bad cases of contused wounds the integrity of the tissues is disturbed not only at the point of the injury, but also at some distance from it, in consequence of disturbances in nutrition due to the infiltration of blood. These changes in the neighbourhood of the wound are not perceptible to the eye of a layman, but are recognised by the surgeon, and on account of this bloody infiltration, if there is any necessity for an amputation, he performs it at a point not too near the injury.

Hæmorrhage in Contused Wounds.—When large arteries and veins are injured, such as the femoral, brachial, or axillary, the hæmorrhage, as a general thing, is slight, or may even be entirely absent, for the reason that the injured vessels are crushed with the other parts, or subjected to torsion, in the same way as described in § 28, for checking hæmorrhage. At the same time, after such severe contusions there is a high grade of nervous depression, of wound stupor or shock (§ 63). As a result of this shock the cardiac activity is

reflexly diminished and the arteries are contracted, and hence the tendency to hæmorrhage from the injured and contracted arteries is decreased. During the next few days, when the shock passes off and the action of the heart becomes stronger, secondary hæmorrhages may readily occur from the crushed, torn, or thrombosed arteries, and may cause the death of the patient unless prompt aid is at hand. It is on account of these dreaded secondary hæmorrhages after contusions that patients with such injuries should be carefully watched. The hæmorrhages may occur on the first to second day with the abatement of the shock, or they come on later, on the fifth to the tenth day, and sometimes later still. The later secondary hæmorrhage may be caused by the sloughing away of the contused portion of the wall of the vessel which has become necrotic, or by suppuration of a thrombus, or by erosion of the artery, as a result of suppuration in its immediate vicinity. But the primary hæmorrhage in contused wounds is not always slight; it often enough happens that there is a considerable amount from both arteries and veins. This is particularly apt to be the case when the arteries are incompletely torn, so that the injured vessel cannot retract or contract. Under these conditions hæmorrhages into the surrounding tissues will also be observed, forming so-called traumatic aneurisms similar to those following punctured wounds of arteries.

III. **Lacerated Wounds.**—Lacerated wounds present essentially the same peculiarities as contused wounds. The larger lacerated wounds have, in general, a mangled appearance. Tearing away of entire extremities—the upper or lower, by machinery, for instance—belong to the severest class of injuries which a surgeon ever sees. In such cases the injured person shows all the symptoms of severe shock, in consequence of which death not infrequently follows. Even when entire extremities are torn away there may be no hæmorrhage of any importance, for the reasons stated above. In the hospital at Zurich an arm, including the scapula and clavicle, has been preserved, which was torn away without causing death by hæmorrhage, as the axillary artery was twisted on itself as in torsion.

Further Course of Contused and Lacerated Wounds.—The further course of contused and lacerated wounds depends upon the severity of the injury, upon the introduction of micro-organisms at the time of the injury or subsequently, and whether the wound receives antiseptic treatment at as early a period as possible. Even very badly contused and lacerated wounds may heal without any marked secretion or suppuration if they remain covered by an aseptic blood-clot beneath an antiseptic dressing. The time which contused and lacerated wounds require for healing is longer than that necessary in other wounds. In

the case of contusions of any gravity, the wound resulting from the injury usually "purifies itself" from the superficial, mortified, or half-dead tissues, by giving off a discharge or secretion which is at first bloody, then serous, and finally purulent. When the wound is treated aseptically the discharge has no odour, but if putrefactive changes take place it is discoloured, dirty, and often has a characteristic smell. The mortified (gangrenous) and half-dead tissues are cast off by suppuration —that is, at the boundary line between the healthy and dead parts, at the so-called line of demarcation, there ensues a vigorous proliferation of the tissue cells and a collection of wandering cells. Subsequently a cellular and vascular granulation tissue forms, from the surface of which pus is given off in large quantities. By this demarcating suppuration the dead parts are separated from the living. The casting off of the dead tissue goes on with different degrees of rapidity, depending particularly upon the vascularity of the injured tissue. Hence it follows that in the case of dead portions of tendons, fascia, and bone, the process takes a particularly long time. Still there are great individual differences in this respect.

Contused and lacerated wounds offer, in general, a favourable medium for bacteria, especially the former. The micro-organisms usually enter the wound at the moment of the injury—for example, when upon a dirty street a wagon-wheel passes over an extremity; or the instrument which inflicts the injury, the dirty clothes, or the skin of the patient, are the means by which the bacteria are carried into the wound. As a result of the presence and development of the bacteria in the wound, the various infectious-wound diseases can originate. These have been described in § 66 *et seq.* After extensive contused wounds, those spreading, septic forms of cellulitis, which we have studied in § 70, are particularly apt to occur. If a contused wound has cast off its mortified layer, and has passed into the stage of granulation, the healing is ordinarily assured if no transgression is made of the rules of antisepsis.

The more minute anatomical changes which take place in the healing of a wound, in the formation of the scar, and the cicatricial contractures, etc., have been described in § 61.

As regards the course of injuries of particular regions of the body, I must refer the reader to my Text-Book on Regional Surgery.

§ 88. **The Treatment of Wounds of Soft Parts.**—The treatment of every fresh wound of the soft parts is conducted upon antiseptic principles, in the manner described in § 6, § 20, and §§ 44–49. The treatment begins with a careful examination of the wound, to determine whether large vessels, tendons, or nerves have been injured, o

whether a joint or cavity of the body has been opened. Our first care should be the arrest of the hæmorrhage, as we have described in §§ 27–30. The following brief description of hæmostasis will suffice: On the extremities it can be best carried out with the assistance of Esmarch's artificial ischæmia. The wound, particularly if a punctured wound, must always be enlarged sufficiently to lay bare the point where the vessel has been injured, and to permit of its inspection. Every large artery in the wound which has been punctured or cut must receive a double ligature—that is, the vessel must be tied on the central and peripheral side of the injured point, as only in this way can secondary hæmorrhage be prevented from the peripheral end of the vessel, or from the puncture in the artery (Rose). If only the central end of the artery is ligated, a secondary hæmorrhage could occur from the unligated peripheral end of the vessel, or the puncture in its wall, very soon after the establishment of the collateral circulation. But the central and peripheral ligation of the artery in punctured wounds, for example, is not sufficient. All the branches given off from the vessel in the neighbourhood of the injury must also be secured at the same time, if one wishes to be perfectly sure of preventing hæmorrhage from the puncture in the artery (Rose). After ligating the main vessel and the branches, the injured portion of the vessel can then be extirpated, though it is not necessary. Injuries of large veins are treated in essentially the same manner as those of arteries. As regards the special technique for ligating arteries and veins, I must refer the reader to § 30.

Temporary Hæmostasis.—Often enough the physician, especially in the country, is not so situated as to be able to immediately and permanently arrest the hæmorrhage, but must be content with provisional hæmostasis carried out by some sort of dressing in order to transport the patient to a hospital. The simplest means of arresting hæmorrhage temporarily consist, as already mentioned in § 29, in applying pressure upon the bleeding point by the finger, a dressing, or an elastic bandage, and in applying pressure upon the afferent artery by the finger, by tourniquets, an elastic bandage, Esmarch's elastic tourniquet (§ 19), and finally by forced flexion—for example, of the elbow joint or the knee if the hæmorrhage takes place in a region supplied by the branches of the brachial or popliteal arteries.

Further Treatment of Wounds of Soft Parts.—When the bleeding has received the most careful attention, it is advisable to examine the wound thoroughly with antiseptic precautions to determine whether and to what extent deeply placed parts, such as tendons, muscles, nerves, or bones, have been injured, and whether the wound is ren-

dered unclean by the presence of a foreign body. The examination should be performed as gently as possible, and an especial warning should be given against the too rough use of the probe. By means of the latter it is easily possible to penetrate a thin, undivided layer of tissue over a joint, over the peritonæum, the pleura, etc., and thus change a relatively simple wound into a complicated one. We shall go into the treatment of penetrating wounds of joints or of the cavities of the body in another chapter (§ 123, Wounds of Joints). If it is found that muscles, tendons, or nerves have been divided, they must be reunited by sutures.

Tenorrhaphy—Tendon Suture.—The best method of performing tenorrhaphy is Wölfler's. He passes the suture through the tendon stumps transversely, about one centimetre from their free ends, either once or repeatedly, and then ties the ends of the sutures together. The two ends of the tendon can then be sutured to the surrounding tissue by means of a number of interrupted stitches or a continuous suture. Trnka recommends the use of lateral loops (Fig. 354) for holding the sutured ends in better contact. Witzel recommends the application of a "retention ligature" passed transversely through each stump of the tendon about one centimetre from its cut end; by means of these retention ligatures the tendon ends are drawn together and then united by catgut sutures. Finally, the two retention ligatures are knotted together, and, if desired, the tendon sheath is sutured. Then follow drainage and closure of the cutaneous wound. It is sometimes difficult to find the central end of the tendon, which retracts to a greater or less extent, in consequence of the contraction of the muscle attached to it, and not infrequently the tendon sheath has to be opened for a long distance upwards—best on its lateral aspect—to find the central end. The longitudinal incision made through the skin for searching for the tendon stump should always be placed not over the tendon but to one side of it; this is the best way to avoid a subsequent adhesion of the tendon to the skin. To facilitate the finding of the central end of the tendon, it is also a good plan to explore its sheath with a sharp hook, with which the tendon may be seized and drawn out, or the extremity may be enveloped by an elastic bandage

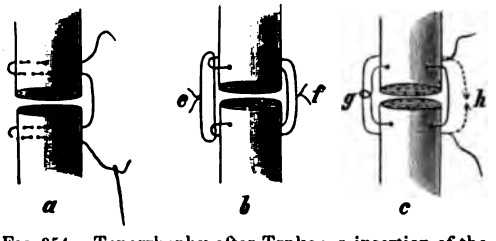

Fig. 354.—Tenorrhaphy after Trnka: *a*, insertion of the suture; *b*, suture tied at *f* and the two loops tied together at *e*; *c*, formation of loops at *g* by means of two sutures, the latter are tied at *h*.

applied from the centre towards the periphery—the reverse of the usual manner of application. The muscle to which the tendon belongs may also be rubbed or pushed down from the outside. Very great difficulty sometimes attends the discovery of the central tendon stump in old cases of tendon division. The retraction of the central end, under these circumstances, is occasionally very considerable, and the above-mentioned methods for discovering the central stump of the tendon are not successful, because the stump is adherent to the tendon sheath. Madelung has advised, in such cases, that the central end of the tendon be sought for by an incision located on the central side of the wound, or rather of the cicatrix, and that the tendon be freed and pushed towards the periphery with a probe, or, perhaps better, with a long, half-curved needle. For the same reasons mentioned before, it is better to make the longitudinal incision to one side of the tendon sheath. If the approximation of the two tendon stumps presents difficulties on account of the tension being too great, as may be the case when there has been a loss of substance, it is advisable to cut a flap with a pedicle from one or each of the tendon stumps. The ends of the tendon are split up to a point near the cut surfaces, and the pedunculated flaps thus formed which are still attached to the tendon are turned down into the defect and united with catgut sutures. Portions of tendons taken from young dogs or rabbits have been successfully engrafted in tendon defects, and attempts have been made to repair losses of substance by interposing strands of catgut (Gluck, Monod). The strands of catgut are absorbed, and in their place tendon tissue is formed. The catgut or silk acts as a framework along which the newly formed connective tissue or tendon tissue grows. But even in cases where the tendon ends could not be united but only drawn near one another, satisfactory results have been observed as regards the function of the muscle involved. In such cases, fibrous bands form between the tendon stumps, as in tenotomy, or the stumps sometimes become adherent to the skin, and the skin finally becomes so movable and extensible that it follows the movements, or rather traction, of the tendon. Duplay and Tillaux obtained a good result by suturing the peripheral end of the divided tendon of the extensor longus pollicis muscle (the cut ends were six centimetres apart, and hence could not be united) into a slit made in the underlying tendon of the extensor carpi radialis longior. Hager and others have likewise successfully united the peripheral tendon stump with the tendon of a neighbouring muscle having a similar action, when direct tenorrhaphy could not be carried out on account of too great a distance between the tendon stumps. By means of transplantation of tendons it is possible to improve or even cure paralysis.

This is done by suturing paralysed muscles or tendons to unparalysed ones. This can be done in various ways. The tendon of the paralysed muscle may, for example, be divided, and the distal end of the same is united to a non-paralysed muscle or tendon, or to the central end of a divided non-paralysed tendon. The tendons may also be divided longitudinally or pedunculated flaps formed, and in this way paralysed and non-paralysed muscles united by suture. A number of surgeons have obtained good results from this transplantation method in paralytic conditions of the leg, foot, etc.—e. g., in paralytic pes varus, pes calcaneus, and pes valgus (see Text-Book of Regional Surgery).

Tenoplasty for Lengthening a Retracted (Shortened Tendon).—H. Sporon has devised the following means of lengthening a tendon which has become shortened by the repair of an injury of the tendon or from some other cause: After exposing the tendon by a longitudinal incision some five centimetres in length, two parallel longitudinal incisions of equal length are made in the long axis of the tendon, one placed one centimetre higher than the other. From the upper end of the higher incision and the lower end of the second, transverse incisions are made in opposite directions (Fig. 357). Thus the tendon, without being divided, can be lengthened an amount equal to the combined lengths of the two longitudinal incisions. Lange (New York) recommends division of the tendon within the muscle, for the purpose of lengthening tendons. This is done with or without tenoplasty (Fig. 355), and consists in dividing the tendon within the muscle with preservation of the muscle fibres on the sides.

Fig. 355. — Tenoplasty by the formation of a pedunculated flap from one end of a tendon.

Fig. 356. — Tenoplasty: *L*, pedunculated flap; *N*, suture.

Suture of Muscles.—Transversely divided muscles are united by interrupted catgut sutures. In cases of loss of muscular substance—as when a piece is torn out of the continuity of the muscle—pedunculated flaps can be turned down into the defect and united by sutures, as in cases of defects in tendons.

Transplantation of Muscular Substance in Cases of Muscular Defects.—In cases of loss of substance in muscles, Gluck, Helferich, and others have proposed the implantation of muscular tissue taken, for example, from a dog. According to the experiments of Magnus and Volkmann, a piece of muscle thus implanted always perishes, and is absorbed in

the same way as an implanted portion of a nerve taken from an animal. As a general rule, therefore, one abstains from the transplantation of a portion of muscle in case of loss of muscular substance; it is unnecessary in small muscular defects, and even when the loss of substance is large the stump of the muscle can become connected by cicatricial tissue—a cicatricial *inscriptio tendinea*, as it were—and not suffer any loss of function. Fig. 358 shows very well that really extensive muscular defects may be so completely compensated for by cicatricial tissue, that the contraction of the muscle as a whole is not disturbed by the interposed cicatrix. Gluck has also attempted to remedy losses of muscular substance by the interposition of strands of catgut, as in defects in nerves and tendons.

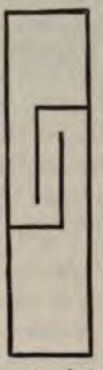

Fig. 357.—Lengthening of a tendon (Sporon).

Regeneration of Muscle.—It is well known that contractile muscular substance has but slight capabilities of regeneration. Muscular defects are always filled up by connective tissue, by cicatricial tissue, and not by new-formed contractile muscular fibres. But in the neighbourhood of the cicatrix, and in slight injuries and contusions of muscles, regenerative changes are observed which have been carefully studied by Weber, Waldeyer, Kraske, and others. At first an enlargement and proliferation of the nuclei of the muscle fibres takes place, and large, mononuclear and polynuclear cells appear, which take the place of the muscle fibres which have disappeared and fill up the muscular interstices. These proliferated nuclei of the old muscle fibres are the formative cells of the new fibres; they arrange themselves into spindle-shaped cells lying side by side, in which very soon a fine longitudinal fibrillated striation is recognisable, and by the end of the third week the first traces of transverse striation make their appearance. Nauwerck, contrary to these teachings, which have been pretty generally accepted, was never able to prove that the proliferated new-formed muscular corpuscles changed into muscular fibres. According to Nauwerck, the new formation of muscular tissue takes place in the manner that E. Neumann described; it proceeds from the old muscular fibres by terminal and lateral budding, and by longitudinal cleavage and segmentation of the old and newly formed muscular fibres. The new-formed muscular fibres penetrate the cicatrix to a greater or less extent. The freer the process of repair is from reac-

Fig. 358.—Partial circular loss of substance in the muscles of the upper arm of a twenty-two-year-old factory girl, resulting from a gangrenous abscess which was caused in her fifth year by the bite of an insect; no disturbance of motion (Uhde).

tion the more complete is the regeneration. Transplanted portions of muscle, as we have said, never retain their vitality; they perish without exception and are subsequently absorbed. In their place a connective-tissue cicatrix forms, which possesses to a certain extent the function of muscle, like every other cicatrix in muscle.

Regeneration of Tendon Tissue.—The regeneration of tendon tissue after division of a tendon proceeds partly from the tendon sheath and partly from the stump of the tendon. After the lapse of two to three days vigorous proliferative changes and numerous caryocinetic figures are observed in the cells of the tendon sheath. The cells in the stumps of the tendon, which degenerate in part in the neighbourhood of the wound, likewise on the fourth to fifth day take a share in the healing process (Viering). The cells of the tendon play a variable part in the formation of the cicatrix; in the main, however, the latter is formed by the cells of the tendon sheath (Busse). By proliferation of the cells of the tendon sheath and those of the tendon proper there originates a granulation tissue, consisting of many-shaped cells, by which the tendon stumps are united. The granulation tissue then gradually changes into normal tendon tissue.

Neurorrhaphy. *The Union of Divided Nerves by Suture.*—There are two methods of performing nerve suture after a nerve has been divided, for instance, in an extremity: the *direct* nerve suture through the substance of the nerve itself, and the *indirect* or *paraneurotic* nerve suture through the connective tissue enclosing the nerve (Fig. 359). Both methods have yielded good results, especially since the introduction of antisepsis. Aseptic catgut is the most desirable suture material for neurorrhaphy. The direct nerve suture is best performed as Wolberg has recommended—by passing a fine needle, flattened laterally, through the ends of the nerve about one centimetre from the cut surface, keeping the suture as superficial as possible and not passing it through the entire thickness of the nerve, so that the nerve fibres are damaged as little as possible. Two lateral sutures are more sparing of the nerve and hold it more securely than one suture through the middle of the nerve stump. According to observations hitherto made, *direct* nerve suture has never produced any bad effects. The *paraneurotic* suture passes, as we have said, entirely outside of the substance of the nerve itself; one suture is applied laterally to the nerve through the paraneurotic connective tissue (Fig. 359), and then, if necessary, one is placed behind and another in front of the nerve, and thus the nerve stumps are brought indirectly into contact. I have found that a combination of both kinds of nerve suture is very advan-

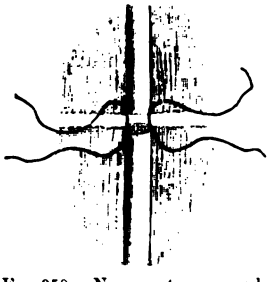

Fig. 359.—Nerve suture passed through paraneurotic connective tissue.

tageous, particularly in cases where there is some tension after the introduction of the sutures. The nerves are, however, so extensible and elastic that by exerting traction upon the central and peripheral stumps it is easy to avoid any tension.

Secondary Neurorrhaphy.—In *old* cases of divided nerves, "secondary neurorrhaphy" should always be performed. The operation has yielded very satisfactory results. Simon and Esmarch have successfully performed neurorrhaphy ten to sixteen months after the nerve has been divided, and in one case Jessop improved the paralytic symptoms by suturing the ulnar nerve nine years after the injury. In old cases of nerve division the stumps of the nerve are sought for, freed from the connective-tissue adhesions, and fresh surfaces made at the ends, which are then united by one or two aseptic catgut sutures.

Operative Treatment of Loss of Nerve Substance.—If there is a loss of nerve substance—a nerve defect—rendering it impossible to unite by sutures the widely separated ends of the nerve, various plans can be followed. In the first place, an attempt can be made to stretch the nerve by traction, so as to make it possible to unite the ends by sutures. If this cannot be done—i. e., if the nerve stumps cannot be brought sufficiently near together—flaps with pedicles may be formed from one or both ends of the nerve, turned down into the defect and united by catgut sutures (*autoplasie nerveuse à lambeaux Létiévant*). I practised this method successfully upon the median and ulnar nerves three months after the injury, and the paralysed right hand of the patient became so useful that she wrote me a letter of thanks a year after the operation. Dittel, Brenner, and others have also had good results with this method.

Nerve-grafting.—Létiévant recommends *nerve-grafting* (*greffe nerveuse*) for loss of substance in nerves. The peripheral end of a divided nerve is united with an adjoining nerve by freshening the latter on one side and fastening the peripheral end of the injured nerve in the freshened area by means of catgut; or the peripheral end of the nerve is inserted between the fibres of the uninjured nerve. By the use of the latter method Désprès inserted the peripheral end of the median nerve between the fibres of the ulnar nerve, and the patient recovered the use of his hand. Sänger cured a paralysis of the musculo-spiral nerve caused by a traumatic defect by suturing the peripheral end of this nerve to the median. M. Gunn has experimented with the method upon animals with successful results.

Löbker's Procedure.—In a case of loss of substance in the flexor muscles of the forearm, involving the median and ulnar nerves, Löbker exsected a portion of bone subperiosteally from the radius and ulna

corresponding to the size of the defect, and then united by sutures to freshened stumps of the tendons and nerves.

Transplantation of a Portion of Nerve into a Nerve Defect.—The transplantation of a piece of one nerve into a nerve defect in another was first performed by Philippeaux and Vulpian. They were successful in causing a portion of the lingual nerve to heal into the hypoglossal. The latter completely regained its function. Recently Gluck has repeated these experiments, successfully implanting a portion of the sciatic nerve three centimetres long, taken from a hen, into a corresponding defect in the sciatic nerve of a rabbit. Eleven days after the operation the sciatic nerve in the rabbit is said to have become capable of conducting mechanical and electrical stimulation. This uncommonly rapid restoration of conductivity in a sutured nerve, and particularly in one which had been united by transplantation, contradicts all the observations hitherto made on this subject. In spite of the perfect union of the transplanted portion of nerve, Johnson, after twenty-three to twenty-four days, was unable to obtain a contraction of the muscles supplied by the nerve in question when he stimulated the latter with the induction current at a point central from the transplantation, but he did cause contractions by direct stimulation of the muscles. At all events, so rapid a restoration of nervous conductivity as Gluck describes, after the transplantation of pieces of nerve into nerve defects, can probably occur in only the most exceptional cases. Perhaps there is in these cases a conduction along collateral nerve branches. As a general thing, the nerve fibres contained in the transplanted piece of nerve will perish; but they prevent connective tissue from growing into the nerve defect, and thus render it possible for the nerve fibrils which develop from the central end of the nerve to readily find their way to the peripheral end. Furthermore, it is my opinion that the nerve fibres in the above-described pedunculated nerve flaps do not persist; but the flaps prevent connective tissue from growing into the nerve defect, and in this way merely facilitate the bridging over of the nerve defect with newly formed nerve fibres. Vanlair has shown that losses of nerve substance—nerve defects—can be repaired by inserting the end of the nerve into an open decalcified bone drain or bone canal. By this means the ingrowth of connective tissue into the nerve defect is prevented, and the bridging over of the defect with newly formed nerve fibres is facilitated by the presence of the open canal. Gluck bridged over a defect five centimetres in length in the musculo-spiral nerve by means of a bundle of catgut; a year afterwards the function was entirely restored.

Corresponding to the gradual regeneration which takes place in the

injured part of the nerve by the bridging of it over with newly formed nerve fibres, the conductivity of a nerve after it has been sutured only returns after the lapse of some time. Within some two to four weeks first sensibility returns in the affected skin area, and then motility, though in exceptional cases the improvement in sensation appears later than that in motion. As regeneration advances gradually from the centre towards the periphery the functional disturbances disappear at first in the parts that are nearest, and much later and more imperfectly in the more distant parts, or those parts may remain permanently paralysed. The return of motility is the only means of determining whether or not a neurorrhaphy has been successful in a nerve with motor and sensory fibres, inasmuch as sensation may become restored by means of the collateral branches of neighbouring nerves. From observations hitherto made, sixteen to nineteen days can be considered as the earliest period at which return of motility begins after a nerve suture; in other cases it began only after the lapse of several months, sometimes ten to twelve. But errors of observation are possible as regards improvement in motility after suturing a nerve, because here also, as we saw, the muscles which are not paralysed may take on the functions of those which are, and more or less compensate for the absence of activity in the really paralysed muscles. By making a careful electrical examination in such cases it is possible to determine whether or not the neurorrhaphy has been successful.

After-treatment of Tendon and Nerve Sutures.—The after-treatment of neurorrhaphies and tenorrhaphies consists principally in placing the affected portion of the body, when possible, in such a position that the suture is relaxed; for example, when the ulnar or median nerve has been sutured above the wrist joint the hand should be immobilised in a strongly flexed position by an antiseptic dressing, made possibly of curved wooden splints, or of a properly bent wire splint like that which Cramer advises. The remainder of the after-treatment, particularly in neurorrhaphy, is very important, and consists in the use of electricity, massage, and methodical exercise of the affected muscles.

The Procedures when a Neurorrhaphy is Unsuccessful.—If a neurorrhaphy should partially or entirely fail, the cicatrix should be divided and the affected portion of the nerve examined, and, if possible, the neurorrhaphy should be repeated. In one case W. Busch exposed the affected part of the nerve ten months after an unsuccessful neurorrhaphy and found that the nerve at the point where it had been sutured was encircled by connective tissue in such a way as to interrupt the conduction; he freed the nerve from the pressure of this connective-tissue cicatrix, and almost immediately the nerve became

capable of conducting the induction current, and directly after the operation the patient could perform active movements which had previously been impossible. Likewise after fractures of the humerus the musculo-spiral nerve is sometimes paralysed by the pressure of the callus, and the paralysis may disappear immediately after removal of this pressure. As a matter of fact, it is well known that the conductivity of a nerve can be easily destroyed by pressure.

Spontaneous Regeneration of the Nerve without Suturing.—What clinical facts are there which bear upon the actual restoration of conductivity in nerves which have been divided and not united by suturing? The observations of Weir Mitchell, Morehaus, Keen, and others prove that recovery takes place in exceptional cases after extensive injuries to nerves without the nerve stumps being united by sutures. Notta saw one instance of spontaneous regeneration within six months after division of all the nerves of the (upper) arm. Tiedemann, in August, 1827, exposed the brachial plexus of a dog in the axilla and divided each nerve, excising from them a piece two to two and a half centimetres long. Complete paralysis of sensation and motion followed in the affected extremity, but in the course of the years 1827 and 1828 sensation and motion returned entirely. In June, 1829, the dog was killed, and it was found that the ends of the nerves had been reunited by medullary nerve fibres. Schiff excised five centimetres of the vagus nerve in a dog, and after several months demonstrated restoration of the conductivity of the nerve without neurorrhaphy. Langenbeck and Hueter observed a restoration of conductivity after laceration of the brachial plexus in a Prussian officer who was wounded by a cannon ball in the storming of the Düppeler redoubt on April 18, 1864. The left lung was extensively injured, and the first rib was shattered, as was also a part of the scapula and clavicle. In spite of this severe injury the patient escaped with his life. Langenbeck again saw the patient in September of the same year, and his arm was totally paralysed. After the lapse of one year and a half the function of the arm was so far restored by electrical treatment that the patient became again fit for service, and served as an officer in the campaign of 1866. He was killed while battalion commander in the battle of Wörth. Riedinger, Krain, Létiévant, and others have also observed recoveries after nerve division without neurorrhaphy. But all these recoveries are rare exceptions, and the ordinary termination is irreparable paralysis. This is due to the fact that the nerve fibres which have been cut off from their centres, as we remarked before, perish by fatty, granular degeneration, and with them the muscles they supply.

Results of Neurorrhaphy.—With the aid of my own and Wolberg's communications Weissenstein has collected seventy-six cases of neurorrhaphy, and he believes that the operation has been successful in sixty-seven per cent. Among the seventy-six cases thirty-three were secondary neurorrhaphies, of which twenty-four were decidedly successful and others only partially so. The return of sensibility began, for the most part, after two to four weeks. The earliest return of motility began after sixteen days, but in the majority of the cases only after the lapse of months, and twice i

required a year. In one case the paralysed muscles regained their complete usefulness after twenty-six days, though most of the cases took a year. Hodges collected 104 cases of primary neurorrhaphy with 74 per cent. of cures, and 108 cases of secondary neurorrhaphy with 80 per cent. of cures.

Regeneration after Complete Division of Nerves.—The regeneration of an injured nerve takes place essentially as follows: When a nerve has been completely divided, regeneration proceeds from the central end towards the periphery, and it takes place the more rapidly the less the interval between the central and peripheral nerve stumps, and hence most rapidly when the stumps are united by sutures. The newly developed nerve fibres spring from the central stump of the old nerve, and, bridging over the defect, unite with the peripheral stump. According to one view, the old nerve fibres of the peripheral segment, after their separation from the centre, perish irrevocably, and the newly formed nerve fibres from the central end grow, analogously to what takes place in embryonic development, along the peripheral stump into the muscles and skin (Vanlair). According to another view, the fibres of the peripheral stump do degenerate, but after the regenerated central fibres have entered the peripheral stump the latter's fibres likewise take part in the regeneration and unite with the fibres growing out towards them from the central end. Both kinds of regeneration may occur at the same time, and the regeneration of the degenerated fibres in the peripheral stump will take place the more rapidly the earlier the central and peripheral ends are united by sutures. After division of a nerve in man there has never yet been observed a direct union of the divided nerve fibres, a so-called *prima reunio*, with restoration of conductivity within seventy to eighty to ninety hours, as Gluck has observed it in animal experimentation. Kennedy has also observed that the sutured nerve was capable of conducting impulses a few days after suture. It should be borne in mind that the electrical conductivity of a sutured nerve must be distinguished from its real regeneration at the point of suture with restoration of function. Regeneration of the place of suture requires time. After the lapse of about two to three months, sometimes later, the regeneration of, for instance, a large nerve in an extremity is usually completed. If the nerve stumps are not united by suture, and if the distance between the central and peripheral stumps is too great, usually no regeneration of the nerve defect occurs. Under these conditions the central end of the nerve takes on a club-shaped enlargement from the formation of new nerve fibres and new connective tissue. This represents an attempt at regeneration. The so-called amputation neuromata are also examples of such club-shaped enlargements of the ends of the divided nerves. In the most rare and exceptional instances large nerve defects, up to five centimetres in extent, have been restored in man and animals without the nerve being sutured. But, as a general thing, the experiments of Sticker and others show that spontaneous regeneration of the nerve fails when the distance between the nerve stumps amounts to one centimetre.

Regeneration after Incomplete Division of the Nerve.—In incomplete division of a nerve, in contusions, etc., regeneration usually takes place more rapidly. If the conductivity of the nerve has been interrupted by compression, such as would be exerted by a bony tumour, by a callus, etc., immediate restoration of the power of conducting a nerve current has been observed

upon relieving the pressure. A regeneration of the tissues of the brain and spinal cord never takes place in man. But Brown-Séquard has observed regeneration of a divided spinal cord in doves.

With the regeneration of the nerves the excitability of the latter also returns, and, according to Erb, Ziemssen, and others, the power of conduction returns sooner than the local excitability; that is, muscular contractions will at first only occur when stimulation is applied above the point of injury, and not when applied below.

Histological Changes in Nerve Regeneration.—Opinions vary as to the changes which occur in the regeneration of a nerve. In all cases the regeneration begins in the central end. About the third week, small, pale processes are seen projecting from the axis cylinders—i. e., the proximal axis cylinders become prolonged; they grow outwards, and at the same time divide into two or more filaments. These newly formed nerve filaments become longer and longer, and, according to the investigations of Vanlair and others, they grow into the skin and muscles. The young nerve fibres, according to the views of various authorities, are at the outset naked axis cylinders, and then subsequently become covered by the sheath of Schwann. The statements made by some authors, that the young nerve fibres are formed from connective-tissue cells or colourless blood-corpuscles, contradict all our other histogenetic views. According to Büngner, Ziegler, and others the old axis cylinder does not take part in the regeneration, but the new fibres are formed by differentiation from a material called "neuroplasma," which is rich in nuclei and originates from the cells of the sheath of Schwann. These cells are thus the real neuroblasts.

The investigations of many authorities, as we have said, show that analogous regenerative changes in the degenerated fibres also take place in the peripheral nerve stump, but much later than in the central stump. The newly developed central and peripheral nerve fibres grow towards each other and unite. The regenerative changes in the old degenerated fibres in the peripheral nerve segment are disputed by some observers, as we have remarked. As a matter of fact, it is very difficult to distinguish histologically the regeneration and degeneration which go on side by side in the peripheral nerve stump. Mayer has made the important observation that regenerative and degenerative changes occur even in perfectly normal nerves.

Only those fibres which remain connected with their centres are capable of regenerating themselves. The so-called *régénération autogénique*, long insisted upon by Vulpian—that is, the independent regeneration of a portion of nerve cut off from its centre—is founded upon an error, as Vulpian himself has admitted.

The works treating of nerve regeneration are very numerous. Cruikshank, experimenting on animals, was the first to observe, in 1776, complete regeneration of divided nerves. References to the most important literature on the subjects of nerve injuries and neurorrhaphy will be found in a paper on these matters in the Archiv für klin. Chir., Bd. xxvii.

Further Treatment of Wounds of Soft Parts.—The further treatment of wounds of soft parts consists in the most careful *disinfection* of the wound and in the removal of any foreign body which has entered i

uch as sand, dirt of every description, pieces of glass, points of instruments, bullets, etc. By using an Esmarch bandage the search for foreign bodies will be greatly facilitated. The X rays can be used to advantage in determining the location of foreign bodies (see § 124, Gunshot Wounds). We shall return to the extraction of bullets in the chapter on Gunshot Wounds. The removal of foreign bodies from the internal organs and the large cavities of the body is discussed in Regional Surgery.

When the treatment of the wound has been carried out in the manner described, we then proceed, in the case of large, deep wounds, to provide for drainage for carrying off the wound secretion (§ 31). After this, in proper cases, the wound is closed by sutures (§ 33), and an antiseptic dressing is applied (§§ 44–49). All fresh wounds which are not infected or markedly contused are suitable for suturing. If there is much contusion of the parts, sutures should be avoided, especially on the skull, where, after deficient antisepsis, a retention of the secretion from the wound may so easily become dangerous and lead to suppurative phlebitis with secondary fatal meningitis. If the contusion is limited simply to the borders of the wound they can be excised and the wound then closed by sutures. In all cases where there is doubt about the propriety of suturing the wound, it is preferable to omit it entirely or to suture only partially—for example, in the middle of the wound.

Indications for Amputation or Disarticulation.—Amputation or disarticulation is indicated in fresh cases if the soft parts are so crushed and disintegrated that either the repair of the injury is impossible, or, if it should occur, the injured limb would be completely useless. Amputation is also indicated in cases with septic cellulitis, in order to prevent death from sepsis. When amputation has to be performed for fresh lacerated and contused wounds, it should only be carried out in sound, normal tissues, and not within the limits of the contusion. In general, operations should be as conservative as possible, especially those upon the fingers. If all the fingers have to be removed and the thumb only can be saved, this should be done in every case, as a movable thumb is better than an entire artificial hand. In the tearing away of extremities or of parts of them, disarticulations, amputations, or plastic operations are also necessary for improving the stump or for hastening recovery. A stump of bone projecting from the soft parts, after the latter have been torn from the phalanges of the fingers, must always be excised or disarticulated by the saw, chisel, or bone forceps at a point where it will be covered by soft parts.

Dressings, packing the Wound, etc.—The best aseptic dressing for ıtured aseptic wounds consists of sterile gauze and cotton. Small ounds and abrasions of the skin can be covered with different kinds adhesive plaster, pastes, collodion, etc. Small uninfected wounds

closed by a crust of blood, etc., will heal under the scab without dressing. Dusting-powders, like iodoform, dermatol, bismuth, oxide of zinc, etc., are suited chiefly for unsutured contused wounds. Packing with aseptic gauze or iodoform gauze is particularly applicable for large contused and lacerated wounds, with or without injury to bones, joints, etc. After removal of the aseptic packing the wound can be closed by secondary sutures, or the packing may be left to dry and form a firm aseptic scab upon the wound until it falls off of its own accord. In suitable cases—for example, in extensive contused wounds—antiseptic irrigation (§ 49) should be employed. Under certain conditions it is an excellent plan to place the patient in a permanent water-bath (§ 49).

I must refer the reader to § 22 and § 62 for the treatment of the general condition of those who have been injured.

Treatment of Secondary Hæmorrhage.—Any secondary hæmorrhages which occur during the healing of the wound are to be arrested, if in an extremity, by double ligation of the vessel in the wound with the assistance of Esmarch's bandage. The ligation of the principal artery in its continuity above the wound, at the so-called place of election, is only to be recommended when the application of Esmarch's bandage is impossible and the blood wells out from the depths of the wound in such amounts that there is danger of the patient's bleeding to death. In such critical conditions an assistant should stop the hæmorrhage by pressure with the finger in the wound while the main artery is rapidly secured at some easily accessible, centrally situated point. The wound can then be examined more leisurely and the injured vessel tied in the wound by a double ligature. The leaving in place of artery forceps, a firm packing of the wound with iodoform gauze, dressings which exert pressure, digital compression, etc. (§§ 28 and 29), have also rendered excellent service in cases of secondary hæmorrhage from deeply located regions, where the application of a ligature is impossible or difficult.

Suppuration—Burrowing of Pus.—During the healing of the wound, especially if it is a large contused or suppurating wound, one must always guard against any burrowing of pus. If spreading inflammation and suppuration are already present in the wound when it comes under observation, as many incisions as are required should be made, as described in § 70 (cellulitis). The treatment of complications of infected wounds, including the infectious-wound diseases, is discussed in §§ 62–82.

Every wound until it has cicatrised should be treated strictly according to antiseptic rules; these should never be neglected, especially during a change of dressings. In the later stages of repair in the

wound, especially when it is granulating, ointment dressings are to be employed (§ 49). The final skinning over of a granulating wound is often hastened by the occasional use of the nitrate-of-silver stick. By this cauterisation with argent. nitrat. we make the shrinkage of the granulation tissue more rapid and prevent it from growing too luxuriantly. We cover extensive losses of substance in the skin with transplanted skin (§ 42), or by plastic operations (§ 41), etc. The formation of cicatricial contractures is always, as far as possible, to be prevented; but if contractures do nevertheless develop, they should be treated in the manner described on pages 146, 305, and in § 119.

For finding metallic foreign bodies which have become healed up in a wound the magnetic needle has been used with success. By its deviations it can indicate, for example, the location of a needle which has become healed up in the wound (Kocher, etc.). Also for finding bullets which have healed in, the magnetic needle can be used with advantage, particularly in army surgery (see § 124). The X-rays are also used a great deal in locating foreign bodies.

§ 89. **Treatment of the Conditions Following Severe Hæmorrhage—Blood and Common Salt Infusion.**—If, after an injury to large arteries or veins, the hæmorrhage has been considerable, the general weak condition of the patient very often demands, after arrest of the bleeding, the adoption of special measures which must be carried out rapidly and energetically. In the milder cases of swooning after loss of blood, the head should be placed as low as possible, the face of the patient sprinkled with water, olfactory stimulants, such as ammonia, administered, as well as several hypodermic injections of ether; the patient should be placed as soon as possible under warm coverings and surrounded by hot bottles, sand-bags, and the like, besides being rubbed with towels and stimulated with strong wine, cognac, black coffee, etc. It is also a very excellent plan to supply a patient who has lost a large amount of blood with great quantities of heated fluids; they are absorbed from the gastro-intestinal tract more rapidly than under normal conditions, and are a direct means of making good the blood deficiency. In severe cases the lowering of the head should be combined with elevation of the legs, or, better, with the envelopment of the legs in an elastic bandage, in order to prevent the threatening cerebral anæmia and to drive the blood out of the extremities towards the heart, the lungs, and the brain (autotransfusion). In the cases of very extreme anæmia all the above-mentioned remedies will be of no avail in keeping the patient alive, and the only other remedy that offers any hope is the transfusion or infusion of blood or a sterilised physiological solution of sodium chloride.

Transfusion of Blood used to be very frequently practised for threatening death from hæmorrhage, for poisoning by illuminating gas, carbonic oxide, carbonic acid, for septicæmia, and for various internal diseases. At present the belief in the capabilities of transfusion has been given up, and the operation is but rarely performed. With the increasing knowledge of the physiology and pathology of the blood, we have found that the earlier views and presumptions which lay at the foundation of blood transfusion were false. I fully agree with Bergmann and others who, reasoning from physiological facts, consider transfusion not only a useless, but also, as we shall see, a dangerous operation.

Causes of Death from Hæmorrhage.—The cause of death from hæmorrhage used to be ascribed to the loss of red blood-corpuscles, and hence to the impoverishment of the blood in hæmoglobin, or rather in oxygen. But now we know that death from hæmorrhage is dependent upon purely mechanical conditions. It is caused by the insufficient filling of the vascular system, by the fall of the arterial blood pressure, or, in other words, by the purely mechanical disproportion between the capacity of the vascular system and the amount of its contents. For this reason the movement of the contents of the vessels ceases; the heart, which at first continues to beat, is, like an empty pump, no longer able to raise the column of blood and drive it onwards. Hence in such cases the indication is to increase the contents of the vascular system by infusion of some liquid, and for this purpose the blood of man or animals, in its entirety, or defibrinated human blood, used to be employed; but recently the infusion of an alkaline seven-tenths-per-cent. solution of common salt has been largely substituted for blood transfusion (Kronecker, Sander, etc.).

Infusion of a Common Salt Solution.—As a matter of fact, infusion of common salt is better than blood transfusion, and I should always use it in cases of acute anæmia. The recent reports of Cavazzani, Porstempski, and others, which favour blood transfusion, do not influence my views in the least. Landerer, at the suggestion of C. Ludwig and Gaule, has proposed the addition of three to five per cent. of sugar to the alkaline (0.7 per cent.) solution of common salt. The advantage of the salt-sugar solution over the plain salt solution consists, according to Ludwig, in the fact that the former is to be regarded as a nutritive solution, and that, in consequence of its high endosmotic equivalent, blood which contains sugar takes up the parenchymatous fluids more energetically; moreover, the blood pressure rises more rapidly, and the red blood-corpuscles are more apt to remain intact than when a pure salt solution is employed. It is simplest to infuse the salt solution subcutaneously (pages 498, 499).

Dangers of Blood Transfusion.—That the transfusion of blood in any form is not only a useless but also a dangerous operation, the following statements prove. In the first place, we know from the experiments made by Müller and Lesser, under the guidance of C. Ludwig, that all the red blood-corpuscles injected with the blood are destroyed in a few days. The corresponding hæmoglobinuria which accompanies this process is caused by the disintegration of the red corpuscles, or, rather, by the separation of the hæmoglobin from the stroma of the red corpuscles, allowing free hæmoglobin to circulate in the blood. According to Sachsendahl, the dissolved hæmoglobin is the most powerful agent for bringing about a rapid destruction of the colourless blood-corpuscles and a very sudden and marked accumulation of the fibrin ferment in the circulating blood, so that death may occur from ferment intoxication.

Magendie uttered a warning against the use of defibrinated blood, because its injection was followed by very definite disorders, such as rapid respiration, diarrhœa, bloody transudations into the peritonæum, the pleura and pericardium, and even by death. The interesting investigations of Armin Köhler show the possibility of ferment intoxication after blood transfusion. He demonstrated that blood taken from another species, as well as blood from the same species, had a poisonous action. If only ten to twelve cubic centimetres of blood were drawn from the carotid of a strong rabbit, allowed to coagulate, and the blood coagulum then chopped up, pressed between pieces of linen, filtered, and of this defibrinated blood only five to six cubic centimetres were injected slowly into the internal jugular vein of the same animal, it usually died during the injection, from extensive coagulation in the right heart and in all the branches of the pulmonary artery in both lungs. These facts are explainable upon Schmidt's theory of coagulation. The fibrino-plastic substance, and particularly the fibrin ferment, are found free in blood defibrinated in the above manner, and being carried in this state into the circulating blood they excite within the blood channels extensive thromboses. The animal dies in consequence of the ferment intoxication. *Pepsin* and *pancreatin* have an effect analogous to the blood ferment (Bergmann, Angerer). Blood defibrinated by beating or shaking, according to the old method of blood transfusion, is not by any means as rich in the fibrinoplastic substance and in the fibrin ferment as blood which has been pressed in the manner just described, but it is only a difference in quantity; consequently Köhler is right in considering blood which has been defibrinated by whipping not so harmless as has been hitherto supposed. As regards the histocym isolated from the blood by Schmiedeberg, see page 313.

Transfusion of Animal Blood.—In the transfusion of blood taken from another species of animal still other conditions come into consideration. Partly as a result of chemical action and partly as a result of the above-mentioned disintegration of the red blood-corpuscles, the blood of a sheep, for example, is a fatal poison for a dog if injected in sufficient amount into the vascular system of the latter; and again, a dog's blood is just as poisonous for a sheep. After the direct introduction of lamb's or dog's blood into the veins of a man, dangerous symptoms had been observed more than two hundred years ago, and yet about fourteen years ago an attempt was made to reintroduce the transfusion into man of lamb's blood. Chills, fever, hæmo-

globinuria, as a result of the disintegration of the red corpuscles in the circulating blood, and not infrequently death, were the consequences. Panum, Landois, and Ponfick have proved by numerous experiments the dangers of the transfusion of animal blood into man, and, in fact, the danger of transfusion of blood in any form which has been taken from another species. We shall now always be on our guard against a return to the transfusion of animal blood.

Direct Blood Transfusion.—It would be most advantageous if the blood in its entirety could be conducted from the artery of a man into the vein of the receiver. But all kinds of difficulties stand in the way of employing this *direct* transfusion. It is not so easy to find any one who will give blood directly from an artery as one who will give it from a vein. Then, the possibility of the blood coagulating in the conducting tube must be taken into consideration. Furthermore, it is always questionable whether the corpuscles retain their vitality in the blood of the receiver.

Wright and Hertig have recommended decalcified blood for transfusion, as Arthus and Pagés found that it did not coagulate (see page 297).

As a substitute for the introduction of blood into the vascular system, Ponfick has recommended intra-peritoneal transfusion—i. e., the infusion of defibrinated blood into the peritoneal cavity. The clinical and experimental investigations of Angerer, Edelberg, and others have taught that this method should be condemned.

Ziemssen has employed with advantage in chronic anæmia the subcutaneous injection of defibrinated blood at a temperature of 37° to 40° C. into the subcutaneous tissue of the thigh, using, for example, three hundred and fifty grains in about fourteen injections. For acute anæmia Ziemssen and others recommend the subcutaneous injection of a sterilised, physiological, seven-tenths-per-cent. solution of common salt.

Indications for Infusion of Blood and Sodium Chloride.—The indications for undertaking blood or common salt infusion are most frequently a high grade of anæmia after loss of blood, and poisoning by, for example, carbonic-oxide gas and illuminating gas, in which common salt infusion has also repeatedly proved efficacious. The operation is no longer employed for septicæmia or chronic diseases of the blood (chlorosis, leucocythæmia, pernicious anæmia, etc.), nor for chronic marasmus.

General Technique of Blood and Common Salt Infusion.—The transfusion is performed with local anæsthesia in order that the behaviour of the patient during the infusion can be more accurately observed. The operation is not painful, and very often the patients are unconscious. During the transfusion of blood a greater or less amount of dyspnœa and cyanosis is usually observed, and both manifestations not infrequently become so pronounced that the operation has to be suspended. Furthermore, if syncope occurs the infusion should be immediately stopped.

Technique of the Transfusion of Venous Blood.—In venous transfusion with defibrinated human blood, about two hundred to four hundred grammes of blood are drawn from a vein of a strong man into a carefully disinfected glass vessel. The blood is heated on a water bath to about 39° to 40° C. (102.2° to 104° F.), defibrinated by whipping with a clean glass rod, then filtered through clean linen in a glass funnel into another glass vessel kept at

about 39° to 40° C. (102.2° to 104° F.) over a water bath. While an assistant attends to the defibrination and filtration of the blood, a large cutaneous vein —usually at the elbow—is picked out. The finding of the vein can be facilitated by causing it to become distended with a phlebotomy bandage wound around the (upper) arm. After exposing the vein and isolating some 2.3 centimetres of its extent, two catgut ligatures are passed under it, and the vein is gently lifted with the peripheral ligature and opened by scissors. A disinfected glass cannula is pushed into the open vein in the direction of the blood current and secured by the other ligature. The bleeding from the vein is checked simply by lifting the vein by the peripheral ligature, or the latter may be knotted. The glass cannula is filled with blood, and then the warm defibrinated blood is injected by a glass syringe, which is not too large, or a glass jar is used with a rubber tube like an irrigator. About two hundred to three hundred grammes are injected slowly; Hueter recommends the injection of four hundred grammes or more. The entrance of air into the vein and the formation of coagula are especially to be avoided. The strictest asepsis as regards the giver and receiver of the blood must always be observed.

Technique of Arterial Blood Transfusion.—In arterial transfusion (Gräfe, Hueter) the radial or ulnar artery is exposed and sufficiently isolated above the wrist joint. Three catgut ligatures are then pushed under the artery. The centrally located ligature is knotted and occludes the artery, while a simple knot or sling is made with the peripheral ligature, or the vessel is closed temporarily with a small artery clamp. The artery is then opened with scissors between the two ligatures or on the proximal side of the peripherally placed artery clamp, a glass tube is pushed into the hole in the artery towards the periphery and firmly secured with the third ligature. The further course of the operation is the same as above.

After the termination of the transfusion the artery and vein are tied centrally and peripherally, the intervening portion used for the infusion is extirpated, and the glass cannula removed. Hueter claims that the advantage of arterial transfusion lies in the fact that the blood is first driven into the capillaries, and the latter act as a filter for any clot that may be injected; there is, moreover, no danger from the entrance of air.

Technique of Direct Blood Transfusion.—In the direct conduction of blood from an artery into a vein the above rules are followed—i. e., a glass cannula is tied into the vein of the receiver and one into the artery of the giver of the blood, and both are connected by a rigorously disinfected rubber tube in which a glass tube is sometimes interposed to control any coagulation.

Technique of Salt Infusion.—In the infusion of salt solution, which should be undertaken as soon as possible after the hæmorrhage and with the strictest asepsis, a sterilised seven-tenths-per-cent. solution of common salt warmed to about 39° C. (102.2° F.) is used, which is rendered alkaline by the addition of sodium hydroxide or potassium carbonate. Szuman recommends aq. destil. 1,000, sod. chlorat. 6.0, sod. carb. 1.0. For one to one and a half litres of a seven-tenths-per-cent. solution of common salt about three drops of sodium hydrate are sufficient. According to Kronecker, the solution of salt should be 0.73 per cent. and *neutral*—alkaline liquids may prove dangerous—or the above-mentioned salt-sugar solution of Ludwig's may be used. For infu-

sion, a glass funnel is employed, or a glass flask with a tube at th connecting it with a rubber tube and a glass cannula. The infusio take place under no higher pressure than exists in the large veins. son states that this is represented at the most by one centimetre of or thirteen centimetres of the sodium-chloride solution—i. e., the flask should not be held higher than 0.13 to 0.25 millimetre above t ing in the vein. During the infusion the body, especially the ab viscera, should be vigorou saged. Five hundred cub metres at the least are and in severe cases of rhage about one thousa teen hundred cubic cen The infusion should not ried on too rapidly, about ninety cubic centimetres jected in a minute. The of salt infusion has so very encouraging. The re fusion, according to the ex we have had with it, sl preferred to the *arterial*.

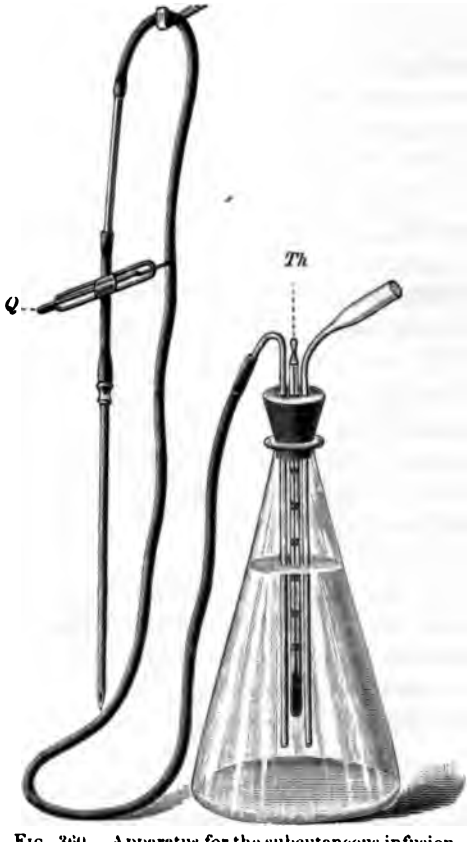

FIG. 360.—Apparatus for the subcutaneous infusion of a saline solution, consisting of a glass vessel with a rubber stopper having three holes; a thermometer (*Th*), a rubber tube with an interposed glass tube, a stop-cock (*Q*), and a hollow needle.

Kümmel likewise warn infusing salt solution int *tery*. After the infusio glass syringe of about fi dred grammes of a six-te cent. alkaline salt solut the radial artery, gangre skin followed, rendering sary to amputate the for tween the lower and midd

Subcutaneous Salt In According to my own ex the subcutaneous infusi sterilised seven-tenths-p solution of common salt i ingly good. The investig Ziemssen, Samuel, etc., h onstrated that the syste when the activity of the impaired, is still able to into its circulation gre tities of salt solution injected subcutaneously. It is injected th hollow needle into various parts of the body, particularly beneath over the abdomen, by means of some apparatus like that of Sahli's, il in Fig. 360; five hundred to one thousand cubic centimetres, warm C. (102.2° F.), are injected during five to ten to fifteen to twenty minutes, according to the nature of the case, and absorption is has

gentle rubbing (massage). I have seen remarkable results in acute anæmia, and in collapse after prolonged operations on weak individuals. In proper cases several litres of salt solution can be injected subcutaneously on several different days. In one patient with chronic mercurial poisoning Sahli washed out the body, as it were, with twenty-one litres of salt solution in eight sittings; each time two and a half to four litres were infused subcutaneously. However, a therapeutic success was not obtained, since the mercury could not be demonstrated in the urine.*

Infusion of Warm Water.—In one case Coates made a successful injection of six hundred and fifty grammes of pure warm water into the cephalic vein.

Milk Infusion.—At the end of the eighteenth century Muralto recommended the injection of milk instead of blood. But Landois and others have shown by animal experimentation that the procedure is to be condemned as directly dangerous to life; its results are marked disturbances of circulation, coagulation, and emboli. Vigezzi has recently tested experimentally the infusion of milk into veins, and he states that acidified milk brings about the above-mentioned dangerous manifestations, but that milk mixed with an alkaline solution is entirely harmless.

§ 90. **Burns.**—Burns originate in a great many different ways—e. g., by direct contact of the affected portion of the body with a flame, or by the explosion of powder, illuminating gas, "fire-damp," etc. Fire-damp occurs in coal mines in particular, and causes an explosion if mixed with a double volume of oxygen or a tenfold volume of air and brought in contact with a flame. Burns are very often due to the action of hot gases, steam, liquids, hot solid bodies, such as metals, etc. In this class of cases belong the injuries caused by caustic substances, such as concentrated acids (sulphuric acid, nitric acid, etc.), and by caustic alkalies. Comparatively mild burns of the skin are caused by the sun's rays.

Symptoms and Course of Burns.—The clinical course of a burn depends upon its intensity and extent. The intensity of the burn is conditional upon the degree of the heat and the duration of its action. The purely local manifestations may occur in three different degrees of severity: First degree, *hyperæmia;* second degree, *bleb formation;* third degree, *eschar formation.*

Burns of the First Degree.—*The first degree* is characterised by a painful redness and slight swelling of the skin—i. e., by a dilatation of the capillaries, with a slight exudation of serum, as in erythema, or in a mild inflammation. In the mildest cases the redness disappears in a short time and nothing follows. Very frequently the horny layer of epidermis is cast off in the form of small scales or patches. In the *second degree* of burn we observe, in addition to the manifestations of the first degree, the development of small and large *blebs*, which are

* Sahli, Samml. klin. Vortr., N. F., No. 11.

filled with a watery, transparent, or slightly yellow serum, and here and there with serum mixed with blood. These blebs either develop immediately or in the course of the next few hours after the reception of the burn. The blebs are usually located in the epidermis, and the contents raise the horny layer from the underlying layer of the rete Malpighii. The rapid development of the blebs in a burn has not yet been clearly explained. In burns of this second degree the swelling and pain are usually very considerable, especially at those points where there is much tension, or when the blebs are removed and the very sensitive reddened corium is exposed to the air. If the blebs break or are artificially opened, the epidermis beneath the portion that has been lifted up forms a new horny layer within three to six to eight days, and from this the shreds of the old horny layer can be easily removed. If the true cutis is exposed, or if the latter is involved in the burn, suppuration often ensues; but it can be entirely prevented by antiseptic dressings, after previously carefully disinfecting the parts. These latter cases form the transition to burns of the *third degree*, in which, as a result of the action of very severe heat, an *eschar* is formed. The appearance of the eschar varies greatly, being ashy grey, brown, yellow, or black in colour, and either moist or dry. The separation of the eschar is brought about by the ensuing suppuration, which can be limited or prevented by antiseptic treatment. In burns of the third degree the difference between individual cases is very great, and they include burns varying from a partial destruction of the cutis to a complete carbonisation of an entire extremity. Hence it follows that the division of burns into three degrees is somewhat illusory, and there have been surgeons who have distinguished seven to ten degrees of burns. But the division of burns into three degrees is, on the whole, the best.

FIG. 361.—Cicatrix resulting from a burn with boiling water, observed in a boy five years old.

The casting off of the burned tissue occasionally takes a very long time, especially when bones are involved. When the eschar has been removed, and a correspondingly large granulating wound surface has taken its place, the skin gradually forms over it, as described in § 61. A very extensive destruction of skin is often observed after burns causing great obstacles to repair. The cicatrix not infrequently giv

rise to various disturbances of function and to deformities, among which mention should be made of ectropion of the eyelids, adhesion of the chin to the chest, contractures of joints in the extremities, etc. (Fig. 361). These cicatricial contractures are best prevented by the transplantation of large, fresh cutaneous flaps with pedicles, or by skin grafting.

Constitutional Symptoms after a Burn.—The constitutional symptoms observed after the reception of a burn depend in the first place upon the extent of the burn. It is generally accepted that when more than half the surface of the body is burned even to a slight extent death is certain to follow; in many cases death ensues when the burn involves only a third of the body. The carbonisation of an extremity is, in general, better borne than an extensive slight burn of the surface of the body. After extensive burns death ensues either immediately after the injury or in the course of the first or second day, or after several days or weeks—i. e., either in the stage of inflammatory reaction, or in that of suppuration and exhaustion.

Immediately after the reception of an extensive burn the patient is usually in a state of great excitement; he complains of severe pain in the injured part, and often cries and screams. The mind is at first entirely clear. In the cases running a rapidly fatal course the patients are very restless and toss about in bed; delirium and convulsions come on, the thready pulse is extremely rapid, the temperature of the body is below normal—sometimes as much as 3° to 5° F.—the respiration is superficial and rapid, the extremities are cool, and death usually follows with increasing symptoms of collapse and coma. The lowering of the temperature occurring, as a rule, in extensive burns of the skin is due to the abnormally increased radiation of heat from the dilated vessels in the affected parts which have been robbed of their protecting epidermic covering. In a number of cases of burns very pronounced excitement is present until shortly before death, while other patients lie quietly in a state of apathy. There is often vomiting and great thirst. The urine, in the majority of instances, is very scanty, and occasionally there may be more or less complete anuria, and not infrequently hæmoglobinuria. The latter is a result of the destruction of the red blood-corpuscles which were in the vessels of the affected part at the time of the burning. If the patient survives the first two days much has been gained, but after the lapse of five to six days, in the stage of the inflammatory reaction, the above-described group of symptoms may suddenly make their appearance and cause death within a few hours. In the later stages the cause of death is due essentially, as we have said, to the increasing exhaustion; a violent diarrhœa begins,

with now and then the formation of ulcers in the duodenum, usually in the neighbourhood of the pylorus.

Causes of Death after Extensive Burns.—How is the death which quickly ensues after extensive burns to be explained? The opinions of various authorities differ greatly upon this subject, and as yet no generally satisfactory explanation has been advanced. According to Wertheim, Ponfick, and others, the above-mentioned destruction of the red blood-corpuscles is the main cause of death. The marked diminution in the number of red blood-corpuscles which are necessary for respiration and for metabolism, produces, according to this view, death, with symptoms similar to those in carbonic-acid-gas poisoning. Furthermore, the plasma is diminished, and this causes a thickening of the blood, which may, however, be compensated for on the second or third day afterwards (Tappeiner, Koch). In addition, the sudden destruction of the red corpuscles has in itself a deleterious effect. In consequence of the destruction of the red cells, the hæmoglobin is dissolved in the blood, and this, as we know, is also a means of rapidly destroying the white blood-corpuscles, and of favouring the development of the fibrin ferment, and of extensive coagula in the vessels. As a matter of fact, extensive thrombi, originating *intra vitam*, are found in the vessels of all the different organs; this has been recently demonstrated in man and animals by Silbermann and Welti. Furthermore, larger or smaller amounts of hæmoglobin are frequently found in the kidneys, it being most plentiful in the straight uriniferous tubules, though occurring also in the convoluted tubules and within Bowman's capsule. From the presence of hæmoglobin such kidneys have a dark, brownish-red colour, which used to be erroneously ascribed to excessive hyperæmia. In addition, the kidneys are more or less hyperæmic, and, like the stomach and liver, full of necrotic foci. These necroses become more extensive with the prolongation of life after the reception of the burn (Welti). The diminished excretion of urine is explained by the changes in the kidneys.

According to Salvioli, the cause of death from burns is to be sought for mainly in the formation of numerous thrombi and emboli made up of blood-plaques. In consequence of these blood-plaque thrombi, and in consequence of the increased adhesiveness of the blood-corpuscles, the circulation finally comes to a complete stand-still. After animals have been, as far as possible, deprived of the blood-plaques by venesection and injection of defibrinated blood, they endure severe burns much better, for the reason that the above-mentioned thrombi do not develop.

According to Sonnenburg, the promptly fatal cases of extensive burns die of heart paralysis. The burning acts as an excessive irritation to the nervous system, causing a reflex diminution of the vascular tone.

Others look for the cause of death in the arrest of the activity of the skin and in the formation of different poisonous substances. As a matter of fact, severe burns often run a course similar to intoxications, and it is hence very natural to seek for the cause of death in noxious chemical products.

Catiano has raised the question whether, in extensive burns, a substance found mostly in the skin is not changed, by being rapidly heated, into a poison, the absorption of which gives rise to the disturbances in question.

The sweat of the skin has an acid reaction from formic acid (CH_2O_2). If this is gradually neutralised on the skin by ammonium hydroxide there forms the very easily soluble formate of ammonium. If this salt is rapidly heated it loses water and changes into *hydrocyanic acid.* The symptoms of hydrocyanic-acid poisoning are said to be in every respect similar to those following burns. According to other authorities, death is caused by the accumulation of ammonia in the blood. According to Reiss, the poison formed in burns belongs probably to the pyridin bases. The poison is excreted by the kidneys. If one half to one cubic centimetre of urine from burned mice is injected into healthy mice, the latter die in a few hours with the symptoms of coma and clonic spasms. The alcoholic extract of the urine is particularly poisonous.

According to Lustgarten, Boyer, and others, death is due to ptomaine poisoning. The intoxication is caused by the metabolic products of the bacteria which, lying in the depths of the cutaneous follicles, have escaped the effects of the burn. It is true that the degenerations of the kidney, lungs, brain, etc., which are often present in extensive burns, point to the action of toxic substances. In any case, these parenchymatous degenerations of the internal organs probably play an important part in the fatal outcome of burns.

The causes of death in the later stages of the inflammatory reaction, as well as during the period of suppuration and exhaustion, vary greatly in their nature. The intensity of the burn and the subsequent suppuration, the fever, and the individual peculiarities of the injured person are here the most important factors. Not infrequently death has occurred from pyæmia and sepsis, particularly before the introduction of asepsis. Among the inflammations of the internal organs the most frequently observed are inflammations of the intestines, the kidneys, the lungs, the pleuræ, and the meninges; they are rarely caused by the action of the heat during the reception of the burn, but are much more frequently a result of the gradual alteration in the blood that occurs after the burn.

Duodenitis after Burns.—The origin of the *duodenal ulceration* after burns, mentioned on page 501, has not as yet been clearly explained. Catiano believes that the duodenal ulcers and the intestinal catarrh originate from the destruction of the epithelial layer and the action of the intestinal secretion upon the exposed parts. The epithelial destruction is said to be produced by formate of ammonium, or by the hydrocyanic acid that is formed from the latter. Hunter also is of the opinion, reasoning from his experiments upon dogs with toluylendiamin, that analogously to the way this substance acts, certain similar products of decomposition in the tissues are produced in cases of burns which are excreted in the bile and are capable of exciting inflammation and ulceration in the duodenal mucous membrane.

Since the time that we have been able, with the help of the modern method of treating wounds, to control suppuration and its accompanying fever and prostration, as well as the accidental-wound diseases, cases of death from suppuration and other wound infections after burns have become less common.

Prognosis of Burns.—The prognosis of burns may be inferred from what has been said. The more extensive a burn is, so much the more

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Prognosis of Burns.—The prognosis of burns may be inferred from what has been said. The more extensive a burn is, so much the more

unfavourable is the prognosis, *quoad vitam.* In addition, the location of the burn, as well as the age and constitution of the patient, play an important part. *Quoad functionem*, burns of the third degree, involving the entire thickness of the cutis, are alone to be feared, on account of the cicatricial contractures which may result. Contractures of the joints, abnormal adhesions, such as adhesion of the chin to the neck, adhesions between the two jaws, contractures of the eyelids, etc., result in this way.

Treatment of Burns.—Leaving for the present the treatment of extensive burns endangering life out of consideration, the *local* treatment of burns of the first degree is mainly directed towards the alleviation of the pain. This is best accomplished by the local use of cold in the form of ice-bags and ice compresses; by the use of liquor plumbi subacetatis dilutus with ice; by cold baths; by painting with flexible collodium, unguentum cerussæ or unguentum lithargyri Hebræ (unguentum diachylon) after dusting on starch, or starch with oxide of zinc, dermatol, etc., with or without an occlusive dressing of cotton wool. Protective dressings, according to my own experience, are the best for alleviating the pain. By placing the parts in a proper position—if an extremity, by elevating it—the analgesic effects of the above remedies are materially promoted. In some instances it is advisable to give subcutaneous injections of morphine. In burns of the *second degree*, when blebs are present, it is advantageous to evacuate the blebs through punctures, but not to remove the elevated epidermis, to cleanse the burned area in the usual way with antiseptic solutions (1 to 1,000 bichloride, or three-per-cent. carbolic-acid solutions), and then to apply an antiseptic powder dressing—for example, zinc oxide, bismuth, iodoform, boric acid, aristol, dermatol, etc. As materials for dressings, it is a good plan to use iodoform gauze or sterilised mull covered with cotton, or some other aseptic material, which allows drying to take place. These antiseptic or aseptic dry powder dressings I consider far better for burns than the other kinds of dressings with salves (unguentum simpl., cerussæ, diachylon, vaseline, etc.), or washes (lime-water and linseed oil, equal parts), or solutions of nitrate of silver (arg. nitr., 1 to 100 of water). The dressing dries into a firm aseptic scab, which can be left uncovered by bandages until it falls off of its own accord from the healed wound. In mild burns the formation of simple aseptic scabs, by means of iodoform, dermatol, bismuth, or zinc oxide, without any other dressing, is a very excellent treatment. After careful disinfection of the burn, Nitzsche recommends covering it with linseed oil varnish (1 part oxide of lead dissolved in 25 parts of boiled linseed oil, to which is then added five to ten per cent. of salicylic acid while the oi

is hot); over this a layer of cotton is placed, and pressed down as firmly as possible by an elastic bandage. Healing generally follows under a single dressing. The *antiseptic powder dressings* are particularly good for burns of the *third degree*. In this way the decomposition of the burned tissues is most easily prevented, and the secretion or suppuration is kept as small as possible. The treatment of burns, like any other wound, should always be conducted with the strictest attention to antiseptic rules, and the less often the dressings are changed the better. A. Bidder recommends painting the burned area with thiolum liquidum or powdering it with thiolum siccum, one of the remedies belonging to the unsaturated sulphur compounds of the hydrocarbons. In *extensive burns* the patient should be placed, when feasible, in a *permanent warm bath* (see page 182). The employment of warm water baths seems to me, however, dangerous in the first days following a burn, because they lower the vascular tone, and can in this way cause serious collapse and even fatal paralysis of the heart. The covering of large granulating surfaces with skin can be hastened by the transplantation of Thiersch skin grafts (§ 42), or by the transplantation of large, fresh skin flaps with pedicles (§ 41). This is the best way of preventing the development of cicatricial contractures or abnormal adhesions. If cicatricial contractures or disfiguring strips of scar tissue have developed after a burn, the cicatrix should be excised and the defect closed by skin flaps with pedicles or Thiersch skin grafts. In the milder cases of contractures following burns systematic movements and massage are sufficient. The indications for the amputation of extremities which have been extensively burned are, in general, the same as for crushings and severe contusions of an extremity. The amputation should be performed as early as possible after the first symptoms of shock have subsided.

In very extensive burns involving a large portion of the body the treatment of the general condition of the patient is the first thing to be considered. For the collapse which occurs in conjunction with the burn, the patient should be placed on his back, wrapped up as warmly as possible, and stimulants (wine, whiskey, grog, black coffee, or any warm stimulating drink) should be administered. The subcutaneous injection of ether or camphor is also advantageous, as is the temporary envelopment of the extremities in elastic bandages to drive more blood to the heart (autotransfusion). Restless patients should be given morphine subcutaneously. Blood-letting, which used to be frequently practised, or blood transfusion, should be condemned. On the other hand, subcutaneous salt infusion (see pages 494, 495) in proper cases of anæmia or of collapse is to be highly recommended.

Burns from Lightning.—Lightning produces the effect of an electrical shock and has a tearing and burning action. Sometimes the one and sometimes the other of these effects is the more prominent. If people and animals are directly struck by lightning, death occurs immediately in many cases, probably as a result of the violent electrical shock to the nerve centres, especially those governing respiration and circulation. The autopsy shows changes similar to those in death from asphyxia. There is usually a rapidly appearing and marked rigor mortis (Offenberg). According to Dürek, the anatomical changes brought about by lightning or a strong electric current are as follows: 1, a constant retardation or cessation of the coagulability of the blood; 2, usually circumscribed or diffuse ruptures of vessels along the course of the electric current; 3, sometimes a laceration of certain organs; 4, usually burns at the points of entrance and exit of the electric current. The effects of lightning upon the skin are manifested by all sorts of changes, varying from a simple drying of the epidermis to the severest burns. The so-called lightning-marks upon the skin are well known. They consist of branching, brownish-red zigzag lines, the formation of which is probably connected with the action of the lightning upon the blood. The colouring matter is set free from the red blood-corpuscles by the electrical action of the lightning, and in transuding through the walls of the capillaries or vessels forms marks which correspond to the distribution of the affected vessels (Rollet). Haberda explains the lightning-marks by a paralysis of the cutaneous vessels resulting from the electrical action of the lightning upon the nerves of the vessels. If the person who has been struck by lightning lives, the symptoms vary. The condition of a person struck by lightning is often precisely the same as in concussion of the brain. Paralyses, dysphagia, disturbances of sight, and other nervous phenomena are also observed. Lightning paralyses have in general a favourable prognosis. The true or direct paralyses are to be distinguished from those occurring indirectly from hæmorrhage. In the true lightning paralysis two stages can be recognised: in the first we have to deal with a direct injury to the muscles and nerves caused by the lightning, while in the second we have the picture of a traumatic neurosis (see page 235). Occasionally large vessels are ruptured, followed by death, and now and then extremities are completely severed from the body. From a medico-legal point of view it is of importance that the copper coins, for example, in the pocket of a person struck by lightning, can be fused into a single mass (Kratter).

Occurrence of Lightning Strokes in Man.—Sonnenburg states that in Prussia, from 1854 to 1857, according to the official statistics, five hundred and

eleven individuals were struck by lightning, and 72.25 per cent. of the cases were fatal. The great majority of the individuals affected were struck while at work in the fields. The statistics of Boudin show that in France, from 1835 to 1864, 2,324 people were struck by lightning. During the American civil war, in the summer of 1864, the lightning struck among the Eighteenth Missouri Regiment, which was encamped on a hill, and knocked down an entire troop. Almost all the horses and eighteen men were killed, and all the rest were more or less injured. When a row of men or animals is struck by lightning the first and last in the row appear to be the most endangered. It is noticeable, as Sonnenburg has correctly remarked, that bodies of troops on the march have only seldom been struck by lightning.

Treatment.—The treatment of lightning strokes, particularly of the constitutional symptoms, is purely symptomatic. Resuscitatory measures often have to be resorted to in the form of rubbing the patient, artificial respiration, etc., and these are sometimes followed by success only after a comparatively long time. The treatment of the burns is just the same as described above. If any paralyses are left they usually disappear entirely under electrical treatment.

Sun-burns.—In consequence of the action of the sun's rays upon the uncovered skin superficial burns are produced. These occur in summer time, especially in tourists and mountaineers. The skin becomes red and swollen, feels hot, and is more or less painful (*erythema solare*). After a few days the burned layer of epidermis comes off in shreds from the underlying parts. Other cases present a more eczematous appearance, with the formation of blebs (*eczema solare*). For prophylaxis against sun-burns, sun-shades should be carried or veils worn, etc. People with irritable skins when going on mountain tours should cover the exposed parts of their bodies with vaseline, or ungt. litharg. Hebræ, or with starch powder. The burns themselves, as long as severe pain exists, should be treated with applications of liq. plumbi subacetatis dil. and ice, or with ungt. litharg. Hebræ or vaseline, and then powdered with zinc oxide and starch (1 to 5 to 10).

Sun-stroke or Heat-stroke.—We have yet to consider the so-called sun-stroke or heat-stroke (*insolation*). This is essentially an overheating of the body, and often terminates very quickly in death, particularly in hot climates; but the affection is frequently seen in summer even in our latitudes, especially among young soldiers who have to take long marches in very hot weather. From the experiments of Krishaber, Schleich, and others, we know that the temperature of a man's body, by immersion of the latter in a hot medium, can be made to rise very rapidly, reaching, for example, 40° to 41° C. (104° to 105.8° F.) in thirty to sixty minutes. Individuals thus treated become restless, the respiration gets very frequent, the pulse rises to 160 or 180, the production of urea is increased, etc. The marked rise in temperature observed in individuals who have been sun-struck coincides with

these experiments. In a case which terminated fatally, Bäumler f the temperature of the patient to be 42.9° C. (109.4° F.) one hour his reception into the hospital.

The symptoms exhibited in sun-stroke or heat-stroke are very characteristic. The face is red, the respiration rapid and sighing, the heart's action is very rapid, and the pupils are dilated. The patient is unconscious, delirious, and convulsions often occur. Death takes place in collapse, sometimes very suddenly. In other cases the course is not so acute; symptoms of collapse are then especially prominent, from which the patient may recover entirely. The decreased secretion of sweat which is noticeable in insolation is important, especially as regards the treatment. At first the secretion of sweat is very much increased in individuals who work or march in very hot weather, or with the sun beating directly upon the head; but later it is diminished, probably as a result of the diminution of the amount of water in the blood, and then the above-described symptoms of sun-stroke make their appearance. As a result of the diminution in the production of sweat, the loss of heat by evaporation becomes so much diminished that the heat balance is disturbed, and, in consequence of the increased retention of heat, the temperature of the body rises more or less rapidly above the normal, even to a fatal height (Cohnheim). The albuminuria as well as the hæmoglobinuria sometimes coming on in horses, for example, after severe sweating, are ascribed by Maas to the changes in the blood, especially in the serum albumen and the red blood-corpuscles, due to the great loss of water.

The cause of death in sun-stroke or heat-stroke is partly the overheating of the body and partly the great loss of water from the body, or the alteration in the composition of the blood.

Occurrence of Sun-stroke.—Meyer has recently reported a great number of sun-strokes affecting harvest labourers almost like an epidemic in the summers of 1873 and 1880. He ascribes death to *cardiac paralysis*, due to the increased temperature of the body and to an alteration in the blood which he considers uræmic. He distinguishes three stages of the disease: a prodromal stage, a stage of excitement, and a stage of depression. Among the numerous cases, only one terminated fatally from meningitis and bilateral pneumonia. American physicians have also described regular epidemics of sun-stroke. In many campaigns sun-strokes have formed a considerable part of the diseases and deaths. As Sonnenburg mentions, the Crusaders appear to have suffered especially large losses by sun-stroke and heat-stroke. On the march through Bithynia and Phrygia, in July, 1099, five hundred men often perished on a single day from sun-stroke. During the American war of secession (1861–'64) there were seventy-two hundred sun-strokes, with three hundred and nineteen deaths. As a result of a forced march during very hot weather in 1848, Sonnenburg states that in the Nineteenth Infantry

Regiment of the German army twenty-nine men died. It is a particularly fatal mistake to keep soldiers, while manœuvring or on the march, from drinking water.

Treatment of Sun-stroke.—It is my belief that the treatment of sun-stroke or heat-stroke is dependent upon the last-mentioned facts. For prophylactic reasons, it should be stated that the withholding of drink increases the danger of insolation. Hence a regular supply of water to individuals while at work or on the march is to be regarded, to a certain extent, as a protection against sun-stroke. When the dreaded accident of sun-stroke has occurred, our efforts should be directed towards lowering the temperature of the body, stimulating the secretion of sweat, and combating the weakness of the heart. We try to meet these indications by cold applications and cold baths; by introducing large quantities of water into the stomach and intestinal canal; by the administration internally of stimulants, particularly alcohol; by subcutaneous injection of ether and camphor, and by keeping the patient as quiet as possible. Many authorities have opposed the energetic use of cold applications, cool baths, etc., and advocate warm baths and warm rubbing. I believe that in sun-strokes as vigorous an attempt as possible should be made to lower the temperature of the body by cold applications, and, when feasible, by cool baths. Venesection should not be employed; it is useless, and, in fact, usually causes marked collapse.

§ 91. **Effects of Cold (Freezing).**—There are usually distinguished, as in burns, three different degrees in the effects of cold upon the skin. The first degree is characterised by a superficial, erythematous inflammation, the second by the formation of blebs, and the third by eschar formation. The peripheral portions of the body—the toes and fingers, the feet and hands, the nose and ears—are especially exposed to the danger of freezing.

Symptoms of Freezing.—In cases of freezing there usually occurs, in the first place, a contraction of the cutaneous vessels, in consequence of which the affected skin area appears pale, and in many individuals corpse-like, particularly when the fingers are involved; this is often a result of the action of a very slight amount of cold. After the first contraction of the vessels there follows a dilatation throughout the affected area; the latter takes on a deep red colour, and a more or less pronounced swelling develops, which causes an itching or burning sensation. Severe pains may also occur, especially when the frozen parts are rapidly warmed. In the *first degree* of freezing this inflammatory redness and swelling disappear permanently within a few days. But not infrequently the frozen area of skin has a tendency to become

affected by a constantly recurring redness, particularly the skin of the nose, ears, toes, and fingers. It may even happen that such cutaneous areas, especially the point of the nose, may, in consequence of a sort of vascular paralysis, remain red throughout life. The so-called chilblains (*perniones*) come from a repeated slight freezing of the fingers and toes. The extensor surfaces especially become the seat, in such cases, of a dark or bluish-red swelling, which has a tendency to ulcerate, and the patient is annoyed by severe itching and burning, particularly in bed, during the change from cold to thawing weather, and in summer. Individuals who have to change constantly from cold to hot atmospheres are very apt to suffer from chilblains. Women, and, as a general thing, anæmic people, appear to be most susceptible to these mild degrees of freezing.

In a frost-bite of the *second degree* the affected area of skin assumes a deep red or bluish colour and is covered with blebs. In such cases it is a matter of great uncertainty as to whether there will finally occur a complete *restitutio ad integrum*, or whether we do not have to deal with a frost-bite of the *third degree*, with its termination in eschar formation or in gangrene. Speaking generally, the prognosis of the second degree of frost-bite is much more unfavourable than is the case with burns. Whenever blebs develop after a frost-bite there will follow in the majority of cases a gangrene of greater or less depth. It is very suspicious, in such cases, when the absence of sensibility persists for several days, and when the area of skin—apart from the blebs—appears to be almost normal. In the pronounced cases of freezing of the third degree terminating in mortification of the affected tissues the parts involved are usually entirely devoid of sensation, of a dark blue colour, and covered with blebs and scabs; there is no circulation, as the prick of a needle draws no blood. The gangrene may be either of the dry or the moist variety, depending upon the amount of evaporation of the

FIG. 362.—Dry gangrene from freezing: *a*, line of demarcation.

dead tissue. I saw a case of freezing involving both feet and legs, in a deserter who had wandered many days in the forest during extreme cold with insufficient clothing; both legs were amputated and the patient recovered. When extremities are entirely frozen like this, parts of the toes can be broken off through the joints like glass. The histological changes in freezing consist in a marked inflammatory reaction combined with different retrogressive changes, and the formation of hyaline and fibrinous thrombi in the vessels; these thrombi are probably the chief cause of the gangrene (Recklinghausen, Kriege).

Effect of Cold upon the Body.—The constitutional effect of cold upon the human organism is a matter of great interest. If an individual is placed in a cold medium, he will lose heat the more rapidly the lower the temperature of the medium and the quieter he remains. As long as a person is in a position to perform active movements he can successfully withstand severe degrees of cold, such as — 42° to — 45° C. (- 43° to — 49° F.).

It is not known at what temperature man ceases to live. Temperatures of 24° to 26° C. (75.2° to 78.8° F.) in the rectum have been repeatedly recorded during the winter time in drunken people who afterwards—generally within a few hours—completely recovered. Cohnheim believes that a complete and rapid recovery is doubtful when the temperature in man goes down to 20° to 18° C. (68° to 64.2° F.). The symptoms manifested by man correspond entirely with those obtained by animal experimentation. When a person becomes very cold there is a pronounced apathy and sleepiness, the pulse and respiration are slow, and the pupils are widely dilated and react sluggishly. Adolph Schmidt found in the blood of a frozen person large numbers of hæmoglobin crystals. The hæmoglobin was in the form of parahæmoglobin, an insoluble modification of hæmoglobin. Death from freezing is favoured by diminished muscular movement. According to Sonnenburg, thirty-six per cent. of those who are frozen are drunk at the time.

Experiments in the Reduction of the Temperature of Animals.—Walther, Howarth, and Cohnheim, experimenting with animals, have studied the consequences of cooling off the organism. If a rabbit or a small dog is immersed to the neck in water at a temperature of about 0° C., or placed in a small vessel surrounded by a cooling mixture, in which movement is impossible, the temperature gradually sinks. If the animal is kept in the cold medium until the rectal temperature becomes 18° to 20° C. (68° F.), as a result of this cooling off a general paralytic condition becomes evident. The animal is no longer able to stand on its legs, and lies as though dead, the contractions of the heart are weak and slow (16 to 20 beats in the minute), the frequency of respiration is also diminished, peristalsis of the intestine ceases,

and the urinary bladder, though filled to distention, is not emptied. The eyes are widely opened, the cornea shows almost no reaction, and the pupils are very widely dilated and almost entirely insensitive to light. If, after the animal has been cooled down to a temperature of 18° C. (64.4° F.), he is allowed to remain in the cold medium still longer, death usually soon occurs in the majority of cases from cardiac paralysis. Animals whose temperature has been reduced to 18° C. ordinarily die when allowed to lie quietly at room temperatures; but their temperature will again rise to the normal if they are placed in a hot medium—for example, in a vessel at a temperature of 40° C. (104° F.). At first the temperature rises very slowly to about 30° C. (86° F.), and then more rapidly; within about two to three hours the temperature of the animal rises from 18° to 39° C. (64.4° to 102° F.). The chilled animal can also be made to become warm again by artificial respiration. As the temperature of the body rises the general paralytic condition disappears, the activity of the heart and lungs increases, intestinal peristalsis reappears, the urinary bladder is emptied, and finally the brain regains its function and the animal is again full of life. But many of these animals die later on after they have recovered their normal temperature, and occasionally such animals are even subject to elevations of temperature with subsequent pronounced emaciation.

According to Catiano, death from freezing is due essentially to cerebral anæmia with secondary paralysis of the respiratory nerves.

Treatment of Freezing.—In treating the mildest grade of frost-bite the affected part should not be warmed too rapidly, but should be rubbed with snow or ice water and then wrapped in wet cloths. A great number of remedies have been suggested for chilblains. It is always important to attend to the general condition of individuals with a tendency to chilblains, and, as a prophylactic measure, to recommend warm coverings for the hands and feet when the cold period of the year comes on. When chilblains are present we try rubbing the parts with snow and ice water, ice poultices, a foot bath of ice water followed by the application of wet cloths, painting the parts with collodion, traumaticin, glue, enveloping them with strips of adhesive plaster, the application of tinct. iodi. followed by a warm, moist poultice, mild caustics, such as dilute hydrochloric acid (1 to 25 or 30 of water), tinct. cantharid., etc. Various kinds of salves have been recommended. Excoriated, ulcerated frost-bites are best treated with iodoform or zinc oxide and starch, or with ungt. litharg. Hebræ (ungt. diachylon), with or without starch, and oxide of zinc. Boeck recommends for chilblains, when the skin is not eroded or ulcerated, applications with the brush of ichthyol, resorcin, tannin, āā 1.0, with aqua, 5.0. This is applied at night, and if the skin is tender it is covered with mull. Massage is sometimes useful in chilblains. For red noses following frost-bite I should recommend punctures made not too deep with the needle point of the Paquelin cautery, or the galvano-cautery,

which causes the redness to disappear without giving rise to a visible scar.

In cases of extensive and deep freezing of the second and third degree involving an extremity, vertical suspension of the limb should be immediately employed to facilitate the restoration of the circulation in the frozen parts. Wet applications may be combined with the elevated position to stimulate the local vasomotor ganglia. If there is necrosis of the tissues, antiseptic dressings with iodoform, or with iodoform and charcoal, naphthaline, etc., or antiseptic continuous irrigation should be used as for burns. If the frozen surface is very large the permanent water bath should be employed (see page 182). If gangrene of an extremity develops, amputation or disarticulation should not be undertaken prematurely, but antiseptic treatment should be kept up until the line of demarcation has become distinct. Spreading inflammation and suppuration are to be combated by multiple incisions, etc.

The treatment of freezing of the entire body is as follows: In the first place, the person who has been frozen must not be warmed too suddenly. He should be carried into an unheated room, rubbed with cold wet cloths, and then placed in a bath at a temperature of 16° to 18° C. (60.8° to 64.4° F.), which is gradually—within two to three hours—brought up to 30° C. (86° F.). It is often necessary and always very useful to perform artificial respiration. Ether and camphor are given subcutaneously, and, as soon as the patient can swallow, alcoholic stimulants are freely administered. Wrapping the extremities in cold wet cloths is excellent for the severe pains in the limbs which occur as the patient returns to life. Bergmann and Reyher recommend suspension of the frozen extremities at the earliest possible moment, to limit the gangrene. There should be no hesitation in applying vertical extension to all four extremities.

§ 92. **Subcutaneous Injuries of Soft Parts.**—The most common and important subcutaneous injury which the soft parts suffer is contusion. It usually results from a bruising or crushing produced by some blunt object, by a thrust, blow, or fall. The soft parts are either squeezed together as a whole, or pressed against a neighbouring bone. The degree of the crush, of course, varies all the way from a slight bloody discoloration, a bloody suffusion or suggilation, to a crushing of the bones and soft parts into a pulpy mass. In many individuals, such as the so-called bleeders (see page 62), a comparatively large effusion of blood not infrequently follows a trifling contusion of the tissues. Furthermore, spontaneous subcutaneous hæmorrhages are not uncommon in bleeders.

The different soft tissues of the body possess a very unequal power of resisting a contusing force. As Gussenbauer's experiments teach, and as daily experience proves, the loose connective tissue and the small vessels and capillaries it contains have the least powers of resistance. The skin, the fascia, the tendons and larger vessels exhibit a remarkable resistance to the effects of a contusing force. In general, two degrees of contusion can be distinguished, the first being the contusion with preservation of the affected parts, and the second with their destruction (mortification, necrosis).

Symptoms of Contusion.—The most important of the symptoms of a contusion of the subcutaneous tissues is *hæmorrhage*. In the majority of cases the extravasated blood comes from the capillaries and veins, the arteries possessing great powers of resistance to violence inflicted by a blunt object. As a result of the laceration of the lymph vessels, there is also an extravasation of lymph, and it sometimes happens that the extravasation is made up mostly of lymph. This lymph extravasate may form a fluctuating tumour, and usually is made up of a citron-yellow or a slightly reddish-coloured fluid having the composition of lymph or blood serum. According to Gussenbauer, these lymph effusions are particularly apt to occur when the skin is more or less displaced by a traumatism from its position in relation to the underlying parts. This displacement causes a laceration of the lymphatic vessels which permeate the subcutaneous cellular tissue. The lymph effusions are consequently usually located in the subcutaneous cellular tissue. As a general thing, the hæmorrhage in subcutaneous injuries, even when large vessels are ruptured, is not dangerous, and, for the most part, soon stops in consequence of the rapid coagulation which usually follows contusions. The extravasated blood is either evenly distributed throughout the contused tissues as a hæmorrhagic infiltration, or it forms small, circumscribed collections which are called ecchymoses or suggilations. The larger collections of blood are called hæmatomata; suffusions, on the other hand, designate more superficial, large, spread-out collections of blood. The extravasated blood distributes itself through the tissues in the direction of least resistance, especially between the fasciculi of connective tissue, between the muscles, in the subcutaneous cellular tissue, etc. If the bleeding takes place into a free cavity, a bursa or a joint, or into one of the cavities of the body, a large collection of blood may result. The collections of blood in the cavities of the body have their special nomenclature, an effusion of blood into a joint being called hæmarthros; into the pleura, hæmothorax or hæmatothorax, etc. Other blood effusions have likewise received particular names, according to the locality in

which they occur—for example, the blood tumour on the head of a newborn infant is called a cephalo-hæmatoma; a hæmorrhage into the brain, an apoplexy, etc.

The hæmorrhages into the large cavities of the body are, of course, dangerous, and are not infrequently fatal, partly because of the amount of blood poured out, which has been able to escape freely, and partly because of the pressure of the extravasation upon organs such as the heart or brain, which are necessary for the preservation of life. It is well known that no less danger attaches to hæmorrhages into the brain itself, the so-called apoplexies by which, apart from other disturbances, the substance of the brain is partially destroyed, and rapidly developing paralyses and death are produced.

As the larger arteries are in general deeply located in the soft parts, and their tough, elastic walls are not easily torn, it but rarely happens that they suffer a subcutaneous rupture. But if it does happen as a result of unusual violence, a pulsating tumour may be formed—a so-called traumatic aneurism (§ 95, Aneurism). When the extravasated blood comes from an artery or from the larger veins the hydrostatic pressure in the connective-tissue spaces usually soon rises to such an extent as to arrest the bleeding, the rupture in the artery being closed by a coagulum. But the presence of pulsation in an extravasation of blood does not in all cases indicate a subcutaneous injury to an artery. The pulsation may be only apparent, and due to the rise and fall of the more or less tense extravasation caused by the pulsation of the underlying uninjured artery. If the apparent pulsation of a tumour is communicated from an adjoining artery, the tumour shows no increase in all dimensions with each systole, but only in a direction at right angles to the underlying artery. On the other hand, an artery may have received an injury, and yet, on account of the thickness of the overlying layers of tissue, it will be impossible to detect pulsation.

The recognition of extravasated blood when the hæmorrhage is superficial presents no difficulties. The hæmorrhages into the skin and subcutaneous cellular tissue are usually seen immediately. In such cases the skin has a dark-red or violet colour, and the greater the hæmorrhage the more extensive is the doughy and fluctuating tumour. As a result of the distribution of the colouring matter of the blood in the tissues of the cutis, there occur within the first few days following the injury various shades of discoloration, of which green, dark green, and yellow usually predominate; they often persist a week or so as a symptom of the contusion which the skin has suffered. The larger the swelling the greater is the subcutaneous extravasation of blood. The more deeply situated extravasations in the extremities cannot be

recognised solely by inspection; it is usually necessary to make use of palpation of the contused soft parts. As a general thing, crushed soft parts are rendered hard by the bloody infiltration; they are thickened and give a feeling of resistance. In the worst degree of contusions, on the other hand, such as those in which the soft parts and the bones are crushed to a pulp by the wheel of a heavy wagon, the affected parts are changed into a shapeless mass devoid of circulation, with or without preservation of the cutaneous coverings.

The comparatively rare extravasations of pure lymph are distinguished from blood extravasations by their slower increase in volume, by the absence of discoloration of the skin, and of all the other symptoms which occur as a result of the coagulation of blood and of the presence of the colouring matter of blood in the tissues.

Fever in Subcutaneous Injuries.—Following subcutaneous injuries of tissue there will sometimes be fever, and yet there will be no symptoms worth speaking of which indicate either inflammation or suppuration; thus in subcutaneous extravasations of blood or subcutaneous fractures there will sometimes be an elevation of temperature to 101° to 102° F., or even as high as 104° F. The cause of this fever is to be ascribed, in these cases, to the taking up of the products of destruction in the tissues by the circulating fluids of the body (see § 62, Fever).

In addition to the elements of the blood and lymph, ingredients of the contused tissues are also taken up into the circulation, especially fat, which may enter the blood and lymph vessels, thus causing extensive fat emboli in the lungs and brain. Fat emboli are particularly apt to occur when the marrow of a bone is injured, as in a fracture. When we come to the latter subject these emboli will be discussed more fully.

Disturbance of Function.—The disturbance of function exhibited by the contused soft parts varies greatly according to the portion of the body affected and the degree of the contusion. A contused joint in which there is a large intra-articular extravasation of blood naturally has its mobility affected. A crushed muscle which has suffered complete rupture will be unable to contract, and the rupture of a nerve, such as a mixed nerve in an extremity, will give rise to a paralysis of the muscles which it supplies.

The pain which is felt in a contusion at the moment the violence is exhibited varies greatly according to the richness of the nerve supply in the affected portion of the body, and according to the amount of crushing sustained by the nerves. If from the effects of the violence a large sensory nerve is injured, the pain at the moment the injury is received is very severe, and the person who has been injured feels the

pain of the contusion not only at the point where the injury was received, but usually all along the course of the nerve, and so at points widely removed from the injury.

Results of the Contusion of a Nerve.—Concussion of the nerve substance is particularly apt to occur in contusions of the skull. When a blow is received on the head, the symptoms of concussion of the brain (*commotio cerebri*) are very plain, and eventually may be combined with so-called focal symptoms indicating an injury to some particular part of the brain, or with symptoms of compression from extravasated blood which may collect between the brain and the skull (see Regional Surgery). In other cases the symptoms of concussion of the brain and spinal cord are produced indirectly, as by falls upon the feet. In the same way a concussion of the nervous system or a contusion of a nerve due to an injury to any part of the body can reflexly affect the central nervous system to such a degree as to give rise to the set of symptoms known as shock (see § 63).

The severity of the injury to the skin is of the greatest importance as regards the subsequent course of the contusion, but the extent of this injury cannot always be determined from the first. The severity of the injury to the skin depends upon the shape of the body inflicting the contusion and the force with which it acts, and upon the elasticity and thickness of the skin, which vary in different portions of the body and in different individuals.

If the skin is contused to such an extent that all the vessels are ruptured and the circulation in the affected area is stopped, the natural consequence is death or necrosis of the tissues thus deprived of nutrition. An area of skin like this contains no blood, and none flows when an incision is made into it, and no pain from the incision will be felt by the patient. Sometimes an apparently dead portion of skin recovers, the circulation becomes established here and there, and then the entire thickness or the entire area of contused skin does not perish. The subcutaneous soft parts and the bones, like the skin, may also suffer a primary necrosis in consequence of a crushing injury. There is another kind of death of tissue which is *secondary* in its nature and caused by the inflammation that takes place after the injury.

If the integrity of the skin has been preserved, absorption of the subcutaneous extravasation of blood usually takes place without any particular disturbance. During the first few days following the injury the contused skin exhibits the characteristic changes which take place in the colouring matter of the blood. The discoloration, which at the outset is dark blue or bluish red, becomes brownish, dark green, green,

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and finally yellow; the yellow stain often persists for weeks or ı
Occasionally the areas of discoloured skin are very extensive.

Absorption of the Blood Extravasation.—The extravasated bloc
sorbed as follows: First the fluid portion of the coagulum is taker
carried off by the lymphatic vessels, and then the fibrinous portion l
liquefied and is likewise absorbed by the lymphatics. Some of the cc
blood-corpuscles disintegrate when coagulation takes place, while otl
forced out of the clot as it coagulates, or leave it, according to Cohnl
spontaneous locomotion. The chief interest in the resorption of extra
blood centres upon the fate of the red blood-corpuscles. Many
get into the lymph chann
are carried by the lymph cu
the nearest lymphatic glands
they occasionally accumulate
numbers as to cause marked s
of the glands and to make a
of their parenchyma present
ly distributed dark-red app

FIG. 363.—Collection of blood in a retroperitoneal lymph gland resulting from a subcutaneous laceration and contusion of the psoas muscle with fracture of the pelvis. × 30.

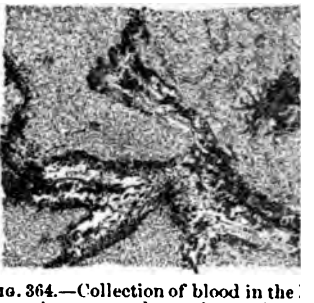

FIG. 364.—Collection of blood in the subcutaneous laceration and con the psoas muscle with fracture o vis. × 80.

I found in a case of fractured pelvis, with a subcutaneous rupture a
tusion of the psoas muscle, a very extensive collection of red blood
the retroperitoneal lymph glands (Fig. 363). Similar accumulations
blood-corpuscles or of blood pigment (Fig. 364) were also present i
organs, particularly the liver. These observations show that red bl
puscles are taken up in great numbers by the lymph channels and e
circulation. Another portion of the red corpuscles disappear *in*
granular degeneration after they have previously become decolour
loss of their colouring matter. The colouring matter of the blood is
through the surrounding parts and a portion of it is simply absorbe
another portion is changed into crystalline hæmatoidin—i. e., into
rhomboid crystals about 0.1 millimetre long, of a yellowish-red to b
colour. Together with these crystalline forms there also occur orang
needles and small angular or indentated rust-coloured particles. Th
toidin is not formed solely by direct transformation of free red blood

cles, but also originates intracellularly—that is, the red corpuscles are taken up by the lymph corpuscles and the colourless blood-corpuscles and are here changed into pigment (Langhans).

Other Terminations of Extravasations of Blood.—The most satisfactory termination for an extravasation of blood is its complete absorption in the manner described above. When the extravasation is diffuse, absorption is the commonest termination. The particles of pigment and crystals of hæmatoidin gradually disappear in the course of months, leaving nothing which recalls the hæmorrhage that has occurred or the injury which the tissues have suffered.

Organisation of the Extravasated Blood.—In severer contusions with larger, more circumscribed extravasations of blood, the extravasation is gradually displaced by new-formed connective tissue, as in the so-called organisation of a thrombus in a vessel (see page 296). In contusions of periosteum, or of bone or its marrow, the product of the organisation is not connective tissue but bone.

Sometimes the organisation of the extravasated blood into connective tissue is confined to the outer layers of the extravasation, as, for example, in cerebral hæmorrhages or in hæmorrhages into the substance of the thyroid gland or of a tumour. In this way there develops at the point where the extravasation occurred a *cyst*—that is, a space filled usually with a yellowish-red fluid and enclosed by a connective-tissue capsule. After the liquid in the cyst has been absorbed a true connective-tissue cicatrix may eventually develop.

Drying, Calcification, Suppuration, and Decomposition of the Extravasated Blood.—In rare cases the extravasated blood becomes dried, or calcareous concretions are formed by deposition of lime salts. The unfavourable changes which the extravasation may undergo are suppuration, and particularly putrefactive decomposition and gangrene. These terminations are only brought about, as mentioned in § 57, by bacterial infection through a cutaneous injury, or, in rare instances, through the circulation, and are seldom observed in subcutaneous extravasations of blood. When infection does occur it is usually due to a superficial cutaneous injury or to necrosis of the skin caused by the injury. It is also to be borne in mind that bacteria may be forced into the skin when the latter is subjected to violence, and they will then find a favourable medium for their development in the extravasated blood and the contused skin.

Absorption of Extravasated Lymph.—The more or less pure lymph extravasations are ordinarily absorbed very slowly, and they sometimes persist for months as a soft fluctuating tumour; it is an exceedingly rare occurrence for them to undergo suppuration or putrefactive

change. The repair of a wound and the regeneration of injured tissues are described in § 61.

Treatment of Contusions.—The treatment of a contusion is, in the first place, directed toward as rapid an absorption as possible of the extravasation. A great number of the slighter contusions get well without assistance in a comparatively short time. If a contusion of soft parts—on an extremity, for instance—comes under observation immediately after it has been received, and if a fracture has been positively excluded, the injured extremity should be placed in an elevated position to diminish the pain and check the subcutaneous hæmorrhage. With the same object in view ice is employed locally, or cold applications, to which may also be added substances like acetate of lead, chloride of ammonium, spirits of camphor, etc. It is always advantageous for arresting subcutaneous hæmorrhage to apply a dressing which exerts a slight pressure. If the skin is intact and there is a considerable extravasation of blood, the latter should be mechanically forced into the interstices of the tissues and into the lymph channels by being gently kneaded and rubbed in a centripetal direction by the thumbs, fingers, or palms. In this manner the absorption of the extravasation is hastened. After the massage, it is often advantageous to wrap the injured portion of the extremity in a flannel, mull, or cotton bandage to prevent a recurrence of the subcutaneous hæmorrhage and swelling. As a general thing, it is a good plan, immediately after the massage, to make the patient move his contused muscles or joint. This increases the effect of the massage and materially hastens the absorption of the extravasation. Massage is suitable for subcutaneous ruptures and contusions like sprains of joints, which can often be cured by this method within a few days; in fact, the effects of massage upon a sprain often seem perfectly wonderful to the laity. The patient may have suffered the severest kind of pain when making the least attempt to stand upon his contused foot or ankle, and yet after massage has been practised but once he will be able to get about with very slight pain, or even none at all.

The massage must be repeated daily, and in the most favourable cases three to five sittings will be enough to effect a cure, while in others the massage must be continued for a longer time. The sooner the massage can be undertaken after the injury the more rapid will be the success.

Technique of Massage.—The technique of massage is not as simple as it appears. It has recently been employed with success for all sorts of troubles. Before beginning the treatment upon the injured portion of the body, it is very often advisable to start with an introductory massage of the healthy

parts on the proximal side of the injury, using centripetally directed strokes of the hand to empty the veins and lymphatic vessels and thus promote the absorption from the injured portion of the body. Massage of the healthy parts on the proximal side of the injury should be employed in all cases where massage of the actually inflamed or injured portion of the body is impossible on account of a cutaneous injury or too great pain. The parts to be massaged and the hands of the *masseur* should first be smeared with lard or vaseline, to facilitate the strokes given by the hand.

There are in general four methods of employing massage: 1. *Effleurage*, or centripetally directed strokes of varying strength made with the palm of the hand or its radial border. 2. *Massage à friction*, or vigorous circular rubs with the hand or finger tips, and particularly with the thumbs, to break up and scatter pathological products. 3. *Pétrissage*, or elevation of a portion of tissue with both hands, or with the fingers of one hand, followed by squeezing and kneading the parts thus lifted. 4. *Tapotement*, or beating and striking the part under treatment with the hand, or with some instrument made of wood, rubber, etc., specially constructed for the purpose. The length of time occupied at each sitting varies greatly; it may be two to three minutes, or as much as five to fifteen minutes or longer, depending upon the extent of surface to be covered. Attempts have been made to substitute for hand massage the use of special apparatus and appliances, particularly in medico-mechanical institutions. Massage with a skilful hand is, however, the most efficacious. Massage should be performed much more often by physicians, and not by the laity, as only the former can feel properly and diagnosticate the pathological changes that are present.

Of course, a great number of contusions are not suited for massage. In this category belong all cases in which the skin has been severely damaged by mechanical violence, or where large vessels have been ruptured, in consequence of which considerable extravasations of blood have occurred, or where, in addition to an extensive contusion and crushing of soft parts, there is also a fracture of a bone. Every cutaneous abrasion, no matter how superficial it may be, must be carefully treated upon antiseptic principles. The subcutaneous extravasation of blood will also be diminished by an antiseptic dressing which exerts pressure. In other cases there may be a scab of dried blood which will protect the cutaneous injury from infection. If suppuration occurs—i. e., if the skin becomes hot, red, and tender, and fluctuation is detected—incisions should be made in the most dependent parts, drainage inserted, and antiseptic dressings applied. Should putrefaction of the extravasated blood set in—i. e., should there be a rapid increase in the size of the inflammatory tumour, with high fever and chills—vigorous treatment must be adopted. Incisions should be made as large and numerous as possible in order that the secretion from the wound may freely escape. The wound should then be disinfected with a 1 to 1,000 solution of bichloride of mercury, or with a three- to five-

per-cent. solution of carbolic acid, and all gangrenous shreds of tissue removed. Early amputation is sometimes indicated when there are extensive gangrenous changes, but, as a rule, such interference is very rarely called for. When large extravasations of blood are absorbed very slowly, or at best but incompletely, it is allowable to open them up, scrape them out, and drain the cavity thus formed. This applies especially to the above-mentioned purely lymph extravasations. They neither coagulate nor become absorbed, and are rather more apt to increase in size; consequently the majority of these cases should be treated by operation. They should be opened as much as is necessary by an incision and scraped out. Furthermore, when a large vessel is ruptured subcutaneously, unless the hæmorrhage ceases, the vessel must eventually be sought for at the point of the injury and ligated on the proximal and distal side of the injured spot, and the intervening contused portion of the vessel extirpated. The special treatment for contusions of joints and bones is described in the paragraphs upon these subjects.

Muscular paralyses following contusions of nerves, if the continuity of the nerve is not interrupted, usually disappear under electrical treatment. If the nerve has been completely divided, neurorrhaphy should be performed in the ordinary way (see page 484).

Subcutaneous Rupture of Healthy Muscles and Tendons.—The subcutaneous rupture of healthy muscles and tendons ordinarily only occurs as a result of the action of great force, such as a violent muscular effort or an excessive strain at the time of the dislocation of a joint, or from direct violence, such as a blow, etc. As a result of excessive muscular exertion, as in jumping, there may occur a rupture of the gastrocnemius or of the tendo Achillis. In a similar manner there may follow a rupture of the tendon of the quadriceps extensor when an individual is in danger of falling and tries to hold himself on his feet by vigorously contracting the extensor muscles of the leg. The ruptures may be partial or complete, and occur either in the muscle or the tendon. Purely muscular ruptures are most common in long-bellied muscles possessing either a very short tendon or none at all, such as the rectus abdominis or the sterno-cleido-mastoid. Not infrequently tendons are torn from their points of insertion with or without a tearing away of bone substance (so-called torn fractures). The tear takes place where there is the least resistance. If muscles and tendons endure the increased amount of strain, their points of insertion, the bony prominences, may break off, and thus there may result transverse fractures of the patella, or fractures of the processus calcanei posterior, in consequence of excessive strain from the quadriceps femoris or gastroc-

nemius with its tendo Achillis. Ruptures of the tendons of the fingers, with or without avulsion of a portion of a phalanx, are of special practical importance; they result most commonly from over-extension or over-flexion with torsion (Brault, Hägler).

The tearing away of the muscles or tendons at their points of insertion on the bones, with or without laceration of bone substance, is particularly apt to occur in traumatic dislocations of joints such as the shoulder or hip.

Very rarely ruptures of muscles or tendons are produced by direct violence—a blow or a thrust.

If muscles or tendons have suffered a loss in their powers of resistance as a result of inflammation or degenerative processes, such as fatty or waxy degeneration accompanying constitutional febrile diseases, a very moderate amount of mechanical violence may prove sufficient to cause a rupture. These ruptures of diseased muscles and tendons are called *spontaneous*, in contradistinction to the ruptures of healthy muscles and tendons.

The *symptoms* of subcutaneous rupture of a tendon or muscle—an accident which is most commonly observed in military practice—consist first of all in the inability to perform those movements of which the ruptured muscle is ordinarily capable. At the injured point it is usually evident that the ruptured ends of the muscles or tendons are separated by a greater or less interval, and that in this gap in the tissues there is a correspondingly large fluctuating extravasation of blood. If the latter is considerable it may render the diagnosis difficult. The patients themselves often direct the attention of the physician to the nature of their injury by positively stating that they have plainly felt or heard a rupture of the tissues.

The subcutaneous muscular and tendinous ruptures usually heal readily under proper treatment, without being followed by any disturbance whatsoever; suppuration is scarcely ever observed. Even when no suitable treatment is adopted, the muscular and tendinous stumps very often heal together by the formation of an interposed connective-tissue cicatrix, such as takes place, for example, after the subcutaneous division of the tendons and muscles undertaken for the cure of club-foot or other joint or muscular contractures. The connective-tissue cicatrix interposed between the muscular and tendinous stumps is at the outset adherent on all sides to the surrounding parts. These adhesions are gradually torn or stretched as soon as the patient again begins to use his muscles.

Even after loss of muscular substance such as follows suppuration, the two stumps of the muscle can become bound together by a con-

nective-tissue cicatrix, a kind of *inscriptio tendinea*, and the muscle be rendered capable of performing its function.

It sometimes happens after subcutaneous rupture of a tendon that, in consequence of the retraction of the central end of the tendon, the two stumps do not directly unite with one another but with the overlying skin. Both tendon stumps in such cases then become adherent to the skin, and the latter may become so mobile that it follows the movements of the tendon, and the latter performs its normal function.

After muscular ruptures subsequent contractures sometimes develop. In this class of cases belongs the so-called congenital form of wry-neck (*caput obstipum*), which is due generally to a partial rupture of the sterno-mastoid muscle, usually the result of operative interference during birth. According to Stromeyer and Volkmann, the contracture is produced in part by a cicatricial shrinkage of the muscular substance, and in part by the oblique position of the head instinctively assumed from the time of birth. According to Petersen, the sternomastoid muscle involved in *caput obstipum* is congenitally shortened. In other cases a contracture after muscular and tendinous rupture is caused by the action of the antagonistic groups. But it is certain, as the division of tendons for contractures also proves, that these so-called antagonistic muscular contractures are not by any means so severe nor so common as was formerly believed to be the case. We shall discuss this question more fully under the subject of contractures of the hand and foot.

Treatment of Subcutaneous Muscular and Tendinous Ruptures.—This consists essentially in approximating as closely as possible the divided and separated ends of the muscles and tendons, and preventing the use of the muscles or tendons, whenever possible, by immobilisation of the affected portion of the body. Wherever it is feasible, an attempt should be made, after division of the skin under antiseptic precautions, to obtain primary union by sutures connecting the muscular or tendinous stumps (see Tenorrhaphy).

Muscular Hernia.—The protrusion of a portion of a muscle through an unhealed rupture in its overlying fascia or sheath is called a muscular hernia. In cases of this description, during the contraction of the affected muscle, a portion of its belly pushes itself through the gaping tear in the fascia or sheath of the muscle and forms an elastic fluctuating tumour (Fig. 365). Herniæ of the straight abdominal muscles and of the muscles of the thigh seem to be the most common, occurring particularly in the soldiers of cavalry and artillery regiments. As Baudin has recently demonstrated, the affection is not so rare as was formerly believed. In the thigh the development of muscular herniæ after subcutaneous rupture of the fascia is favoured by the very slight distensibility of the fascia, by its tense arrangement on the inner

e leg, and by a frequently repeated, excessive stretching of the such as occurs in riding. The observations of Baudin show that a pture of the fascia does not necessarily occur. Much more com- re is a gradual forcing asunder g apart of the fibres of the fascia. t of the poor nerve supply in the ar in the latter is not ordinarily ed by pain. As regards the diag- characteristic for tumours due to herniæ to disappear or become as the points of origin and inser- e affected muscle are separated proximated to one another. liscomfort caused by such a mus- ia is considerable, an operation ndertaken for its cure. The skin the ruptured fascia exposed, and of the rent freshened and drawn catgut sutures. After healing is an elastic dressing which exerts the form of an elastic girdle, pos- a flat pad, should be worn for some time. In mild cases, and when e afraid of the knife, we are forced to confine ourselves to a purely reatment of the affection by an elastic girdle with a flat pad.

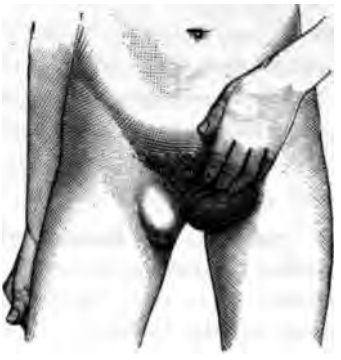

FIG. 365.—Muscular hernia (adductor longus) resulting from a rupture of the fascia, due to a fall from a horse. (Rawitz.)

tions of Muscles and Tendons.—Displacements of muscles ns after laceration of their fasciæ and synovial sheaths have he name of dislocations. In general they are very rarely and mainly occur when the muscle or tendon in question by ent movement slips over a bony prominence where it is held placement of the tendons of the peronei muscles on to the ace of the external malleolus may occur in severe sprains le joint. There is a division of opinion as to the frequency h dislocation of the biceps tendon occurs from the bicipital er the lesser tuberosity of the humerus. According to Cow- islocation is particularly apt to occur in forced elevation of nd the accident is characterised by severe pain in the region ser tuberosity, and by inability to move the shoulder joint. Pitha, and others doubt the occurrence of simple dislocations eps tendon unaccompanied by dislocation or fracture of the of the humerus.

eposition of the dislocated tendons—of the peronei, for ex- an easy matter in recent cases. To keep the tendons in er position after they have been replaced, a suitable retentive hould be applied so as to exert pressure upon the point dislocation has occurred, while the joint is made to assume a

suitable position, which in dislocation of the peronei consists in supinating the foot. As dislocations of tendons are particularly apt to occur when the bony grooves are not deep enough, and as this condition also favours their recurrence, it is occasionally advantageous to make use of Albert's method, and deepen the groove subperiosteally with a gouge and then reunite the elevated periosteum by catgut sutures. Maydl recommends in addition freshening and suturing together the lacerated edges of the tendon sheath. If there is atrophy of the tendon sheath, a portion of the periosteum may be turned over the tendon and sutured to its sheath.

Dislocations of Nerves.—These occur under conditions similar to those described for dislocations of the tendons and muscles. Dislocation of the ulnar nerve from its groove behind the internal condyle of the humerus is a particularly familiar accident. In obstinate cases the bony groove should be deepened subperiosteally with a gouge, or the nerve should be secured in position by suturing its sheath to the fascia or inner border of the triceps tendon and covering in the nerve by suturing the fascia over it to the periosteum (Stabb).

Subcutaneous stretching, tearing, or laceration of the capsules of joints and their ligaments—the so-called sprains—will be discussed under the subject of Injuries of Joints (§ 121).

§ 93. **The Diseases of the Skin and Cellular Tissue.**—The diseases of the skin are very numerous, since it is so much exposed to injurious influences from without, and since it bears such an intimate relationship to the whole organism. This relationship to the rest of the system explains why the skin presents *secondary* symptomatic changes in diseased conditions of the nervous system, the blood, the lymphatic system, and the internal organs.

The trophoneurotic cutaneous affections are extremely interesting. We know that, as a result of long-continued irritation of peripheral nerves, there may occur not only degenerative changes in the peripheral portions of these nerves, accompanied by trophic disturbances, but that also the peripheral changes may advance in the form of an ascending neuritis to the spinal cord and brain. These secondary diseases of the central nervous system may then in turn give rise to trophic disturbances of the skin, to inflammation, gangrene, ulcers, vasomotor disturbances, etc. I should also mention at this place the reflex angioneuroses, in which, as a result of various kinds of irritation such as may proceed from the sexual organs, manifold polymorphous exanthemata including wheals, papular efflorescences, erythema nodosum, etc., may occur. Various acute and chronic infectious diseases are accompanied by cutaneous lesions, and the latter also occur from the internal or external use of drugs.

We shall confine ourselves here to only the most important diseases of the skin in so far as they belong to the province of surgery.

Acute Inflammations of the Skin.—The principal acute inflammations of the skin of interest to the surgeon are erythema, eczema, furuncle, carbuncle, and erysipelas; the latter is described in § 71.

1. **Erythema.**—By erythema (*dermatitis erythematosa*) is understood an acute circumscribed inflammation mainly involving the papillary layer of the skin. In consequence of the inflammatory hyperæmia the skin is reddened and somewhat swollen. The temperature of the affected area is elevated, and there is usually a sharp, burning pain. The anatomical changes in erythema consist in a serous exudation into the space between the most superficial layer of the cutis and the rete Malpighii, and in a more or less pronounced infiltration with leucocytes. The cells of the rete Malpighii are generally somewhat enlarged and swollen. As a result of the exudation, the epidermis is often elevated in the form of small blebs which are filled with serum or pus. Erythema usually terminates in a complete *restitutio ad integrum*, without leaving any visible cicatrix. The epidermis comes off mostly in the form of scales or large flakes. If the irritation continues long enough, small ulcers may occasionally develop from the blebs, but these, too, as a rule, heal very rapidly. The causes of erythema are very varied. Ordinarily the disease originates from a local mechanical, thermal, or chemical irritation; it may thus come from superficial burns or frost-bites, from continued irritation of the skin by wet bichloride or carbolic dressings, or it may be caused by sweat, urine, or pus, particularly in localities where areas of skin rub together, as at the anus, the vulva, in the axilla, or after the ingestion of various kinds of food or medicaments (quinine), etc.

Erythema Multiforme, Erythema Nodosum.—In endocarditis, as a result of infection by micro-organisms, and in all cases of acute and chronic infectious diseases, various forms of erythema sometimes occur, particularly erythema multiforme and erythema nodosum. The etiology of erythema multiforme is extremely varied. In addition to the toxic influences which bacteria exert, a very important part is played by alterations in the nervous system, including both the peripheral nerves and the central nervous system, and by irritations of the skin when the nervous system is normal. According to Düring and others, erythema exudativum multiforme and nodosum are specific infectious diseases.

The Treatment of Erythema consists in great cleanliness and the use of washings and baths. For pure hyperæmia ice and lead-water should be employed, and the parts should be covered with unguentum thargyri Hebræ (unguentum diachylon), or vaseline, and afterwards dusted with starch or oxide of zinc and starch (1 to 5 to 10), and then

covered with cotton. The latter treatment is particularly good when blebs are present; they rapidly disappear under the application of desiccating substances such as unguentum diachylon or vaseline, or when dusted with starch and zinc oxide. But the cause of the erythema should always be taken into account, especially if it is a bacterial erythema—i. e., an erythema occurring in the course of an infectious disease.

2. **Eczema.**—Among the inflammations of the skin in which there is a formation of blebs special mention should be made of eczema, which is sometimes acute and sometimes chronic, and consists in the development of papules, vesicles, and pustules which dry and form crusts. The skin in the neighbourhood of the vesicles is usually more or less inflamed. Eczema, too, is particularly apt to be excited by all sorts of external irritation, such as wet antiseptic dressings of bichloride, carbolic acid, etc. (For the eczema that occurs on the hands of surgeons, see page 179). A large number of very different skin diseases are included etiologically under the term eczema which should really be separated. An important type of eczema is the *eczema seborrhoicum*, in which there is a formation of scales and crusts on those parts of the body which are richly supplied with sebaceous glands, such as the hairy portion of the scalp, the edges of the eyelid, the axilla, etc. (Unna).

Treatment of Eczema.—The treatment of acute eczema consists in removing the cause, such as the wet dressings, and then in the application of drying remedies (fifty per cent. alcohol, brandy) or unguentum diachylon or vaseline, dusting with zinc oxide and starch and covering with cotton, but without gutta percha over it, since the drier the eczematous area is kept the better. If success is not obtained by these methods, a trial should be made with zinc glue (oxide of zinc and gelatine, each one part, glycerine and aq. destil., each four parts) Unna's ointment of benzoate of zinc spread on gauze, Pick's salicylic-soap plaster, Lassar's zinc paste, etc. Chronic eczema is treated in essentially the same way. In addition we use animal preparations—ichthyol (internally and externally), liniments which are allowed to dry on, etc. Peck's bichloride gelatine, the salicylic-soap plaster, Lassar's salicylic paste, Unna's salicylic-plaster mull, two to ten per cent. of chrysarobin or pyrogallic acid in vaseline, are all useful preparations. The Röntgen rays have also been used with success in chronic eczema. Arsenic should be administered internally, and in children oftentimes cod-liver oil. Any constitutional dyscrasiæ, such as gout, diabetes, scrofula, etc., should receive special treatment. The diet should be carefully regulated.

Other Skin Diseases.—According to the different forms and causes of erythema and the skin inflammations in which blebs develop, many varieties of these diseases are distinguished, such as erythema exudativum multiforme, erythema nodosum, urticaria tuberosa, impetigo (pustules drying and forming crusts), etc. We cannot discuss at this place other cutaneous affections like psoriasis (development of dry, white scales), prurigo (inflammation accompanied by the formation of papules), and the various manifestations of syphilis. In urticaria there is an eruption of red itching wheals which are sometimes pigmented. By miliaria is understood an eruption of small, transparent vesicles; by herpes, vesicles arranged in groups—for instance, upon the lips (herpes labialis) or prepuce (herpes preputialis), and on the back (herpes zoster). Herpes zoster occurs along the distribution of some particular nerve, and is sometimes present when changes have taken place in the spinal ganglia and the Gasserian ganglion. The infectious character of herpes zoster is becoming more and more insisted upon; epidemics of this affection have repeatedly been observed (Pick, Kaposi). By pemphigus is understood a cutaneous eruption with the formation of blebs which vary in size from that of a pea to that of a hen's or goose's egg. It has various causes: it occurs, for example, in the course of infectious diseases (sepsis), in injuries and inflammations of nerves, after the ingestion of certain drugs, etc. The views regarding the nature of pemphigus are still very divided; some regard the different types as one and the same disease, while others understand the term pemphigus to include diseases of very variable etiology. Two main varieties can be distinguished clinically: pemphigus benignus and pemphigus malignus. The latter is characterised by early and often primary involvement of the mucous membrane and morphological variations in the ordinary picture of pemphigus. The prognosis is unfavourable—death occurring, according to Kaposi, in about one half the cases. Xeroderma pigmentosum (Kaposi) is a rare skin disease in which the skin becomes atrophied, wrinkled, and parchment-like; furthermore numerous pigmented spots and telangiectases are present. The skin is tense, so that the eyelids and lower lip appear everted and the fingers bent. The disease begins in earliest childhood, its cause is unknown, and it generally results fatally, usually after a long duration and after the formation of malignant tumours. Frank and Sandfort observed in a thirty-three year-old mountaineer a peculiar desquamation of the entire skin of the hands and feet, including the nails. It occurred at a certain time every year. The new skin was as tender as that of a child. Kerion celsi is a skin disease caused by tinea tricophytina, which attacks principally the scalp. The involved portion of skin—e. g., of the size of a silver dollar—is swollen,

Fig. 366.—Neuropathic œdema of the right upper extremity in a woman thirty-two years old, following a fall upon the right arm.

perforated like a sieve, and covered with crusts. Removal of the hair and the use of antiseptic solutions (1: 1,000 bichloride, absolute alcohol, etc.) usually bring about a gradual cure. Hydroa vacciniforme (summer eruption) is a very rare recurring skin disease which occurs chiefly in children on the face and hands, and is caused by the action of the sun. It consists in the formation of papules or vesicles up to the size of a bean. These dry, form a scab, and a more or less deep scar results. Myiasis, a skin disease occurring in animals and man, is caused by the larvæ of two varieties of diptera, the muscides and the œstrides. It occurs chiefly in Central America and Russia. The above insects lay their eggs in summer inside the nose, auditory canal, upon the skin, cutaneous ulcers, etc., of individuals who lie or sleep out of doors. Their larvæ, which creep out in a few hours, penetrate farther into the tissues. The myiasis muscosa sometimes give rise to extensive destruction of the soft parts and suppuration of the cranial and facial cavities, and may prove fatal from sepsis and exhaustion, while myiasis œstrosa is a localised disease with a favourable prognosis. I saw a case of myiasis muscosa end fatally from meningitis. Myiasis of the skin (myiasis dermatosa) has in general a good prognosis, particularly myiasis dermatosa œstrosa, in which, as a rule, the larvæ form passages in the skin of different lengths, either starting from an ulcer or the intact skin. The treatment of myiasis consists naturally in removal of the larvæ. In certain nervous states, such as neurasthenia, hysteria, and Graves's disease, particularly when the blood is in a hydræmic condition, more or less circumscribed œdema of the skin sometimes occurs, running either an acute or chronic course. The cause is mainly an angioneurosis or trophoneurosis (Sydenham, Quincke, J. Collins, and others). In one case of neuropathic œdema of the skin of the upper extremity following traumatism Socin and Bircher obtained a cure by stretching the brachial plexus in the axilla. Certain drugs give rise to different skin lesions in predisposed individuals—e. g., antipyrine, quinine, potassium iodide, salicylic acid, etc. Caspary observed marked pemphigus after the administration of antipyrine. The administration of quinine is followed by different exanthemata (erythema, eczema, purpura, pemphigus, etc.).

All moist cutaneous affections accompanied by the formation of blebs are best treated in the manner described above for eczema—viz., by desiccating dressings of oxide of zinc, with or without previous or simultaneous ointment dressings, such as unguentum diachylon, by dilute alcohol, etc.

3. **The Furuncle.**—By a furuncle is understood an acute inflammation of the sebaceous glands and hair follicles, which is always due to micro-organisms, especially the *Staphylococcus pyogenes aureus* and *albus*. By the penetration of the micro-organisms into the mouths of the sebaceous glands there is first developed a pustule (acne) about the size of a pin-head, which soon enlarges into a very painful nodule the size of a pea or bean. After a few days suppurative softening usually develops in the centre of the nodule. Occasionally the inflammation extends more deeply and spreads into the surrounding parts, giving

rise to a cellulitis with extensive suppuration or necrosis of the underlying fascia. Some people are very subject to furuncles. They sometimes develop simultaneously in various parts of the body in individuals who are otherwise perfectly healthy; the same thing also happens in diabetes, during the convalescence from typhoid fever, etc. It is interesting to note that during the furunculosis occurring in perfectly healthy people, sugar sometimes appears in the urine and vanishes after the recovery from the furunculosis. In hospitals where the antisepsis is defective furuncle epidemics sometimes arise.

Treatment of a Furuncle.—The best treatment of a furuncle is early incision under local anæsthesia with cocaine or ether spray, to alleviate the painful tension and to provide an escape for the pus. Very often it is possible to prevent a furuncle from developing by opening the small acne pustule as soon as it forms and disinfecting it with a one-tenth-per-cent. solution of bichloride of mercury. In large, fully developed furuncles a cruciform incision should be made and the purulent masses carefully scraped out. Ointment dressings of boric-acid ointment or vaseline with iodoform are better than dry dressings. Much time used to be lost in the treatment of furunculosis by a purely symptomatic procedure, such as the employment of ice and warm, moist applications. When there is an extensive infiltration of the parts surrounding the furuncle, the moist, warm applications are no doubt serviceable; but the main point is always to lessen the tension by an incision at the earliest possible moment, and to provide a means of escape for the pus, in order to prevent the development of a cellulitis with extensive necrosis of tissue. As an abortive treatment for furuncles the parenchymatous injection of three per cent. carbolic acid or the application of a drop of pure carbolic acid are sometimes employed.

The treatment for general furunculosis consists in the use of lukewarm baths, in regulating the diet, and in the internal administration of arsenic. The local treatment is in general the same as that given above. Ten per cent. β-naphthol paste and 10–50 per cent. resorcin paste are also useful. In diabetes, regulation of the diet is particularly important (meat, wine). It is well known that in diabetes extensive gangrenous processes sometimes occur in conjunction with a furuncle; in this condition the knife should be used with caution.

4. **Carbuncle.**—By carbuncle is understood a collection of furuncles lying close together, giving the skin the appearance of being perforated like a sieve by separate foci of inflammation. Here also we generally have to do with infection by the *Staphylococcus pyogenes aureus* and *albus*. The carbuncle has a more pronounced tendency

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than the furuncle to extend peripherally. It occurs particularly on the neck, back, buttocks, cheeks, and lips. The carbuncle in healthy people, as a general thing, is not dangerous; but it can become complicated with extensive phlegmonous suppuration and necrosis of the skin and deeper tissues, with venous thromboses, and may terminate fatally from septicæmia or pyæmia. In a carbuncle involving the lips, cheeks, or neck there is reason for fearing an extension of the inflammation to the cranial cavity, as cases in which this happens often run a rapidly fatal course. When the patient has diabètes the gangrenous destruction of tissue is often very considerable, and not infrequently, as a result of the extensive gangrene, and in spite of energetic and suitable local surgical treatment, death will occur from sepsis or pyæmia.

The Treatment of a Carbuncle is essentially the same as for a furuncle, and the incisions should be made as early as possible. Their number will depend upon the extent of the inflammation, though in small carbuncles it is sufficient to make one longitudinal or cruciform incision down to healthy tissue. If the suppuration and necrosis of the tissues are sufficiently far advanced, I remove the softened gangrenous and suppurating parts with a sharp spoon, scissors, and forceps, and disinfect the focus most carefully with a one-tenth-per-cent. solution of bichloride of mercury. For dressings I prefer iodoform, dermatol, or zinc oxide with boric ointment or vaseline. Moist warm applications are excellent for softening areas containing an inflammatory infiltration. Later on we should always be on the alert to prevent any burrowing of pus, any retention of the discharges, etc. According to the extent of the inflammation, the antiseptic dressing should be changed once or twice a day, or every two to three days. This energetic operative treatment of a carbuncle is better than the old-fashioned symptomatic method, which avoided the use of the knife. The strength of old people, in particular, should be sustained by nutritious food, by wine, etc. Cutaneous defects—loss of skin substance on the face, for example—should be remedied by plastic operations.

The anthrax carbuncle (*pustula maligna*) is described in § 77, and acute inflammation of the skin and cellular tissue (cellulitis) in § 70.

5. **The Chronic Inflammations of the Skin and Subcutaneous Cellular Tissue—Lupus.**—Of the chronic inflammations of the skin I shall first take up lupus, a disease which is to be regarded, in the main, as a tuberculosis of the skin (see § 83). As a proof of this, tubercle bacilli are found in the lupus foci (see page 416). By the inoculation of lupous tissue into the peritonæum or the anterior chamber of the eye of guinea-pigs and rabbits unquestionable typical tuberculosis is pro

duced. The toxines of tubercle bacilli can also, as stated on page 418, cause cutaneous diseases in tubercular subjects; tubercle bacilli can not be demonstrated in these chronic exanthematous lesions (Boeck). As regards the pathological changes in lupus, I must refer the reader to the detailed description of tuberculosis in § 83; we shall discuss here only the following clinical aspects of the disease. Lupus is particularly apt to occur on the face, though it also appears on other portions of the body, such as the extremities. Lupus originates by the tubercle bacilli finding lodgment in the normal pores of the skin, or in some wound which may be a very small cutaneous injury or an abrasion. Not infrequently it may be proved to have originated by inoculation or by contact with people having tuberculosis. This lupus coming from inoculation, as a result of a direct infection, and occurring in individuals otherwise perfectly healthy, I believe to be much more common than has hitherto been supposed. Besnier, Unna, and Phillipson have observed an acute dissemination of lupus nodules over the entire body. In lupus of the skin the pathological changes consist in the formation of small nodules made up of typical tubercles. The nodules may disappear by absorption, or break down and suppurate, giving rise to corresponding losses of substance in the skin—i. e., ulcers. In combination with the nodules and ulcers a diffuse infiltration and hyperplasia of the tissues is frequently observed. The epithelium often proliferates in an atypical form growing into the subcutaneous cellular tissue and giving rise to formations similar to carcinoma.

As regards further pathological changes in lupus, I must refer the reader, as I have before remarked, to the detailed description of tuberculosis in § 83. We shall confine ourselves here to its clinical and therapeutic aspects.

Clinically, three forms are distinguished: lupus maculosus (or lupus exfoliativus), lupus exulcerans, and lupus hypertrophicus. In *lupus maculosus*, red or yellowish-brown smooth spots are formed, with a cracked, exfoliating, epidermic covering (lupus exfoliativus). In some cases lupus maculosus extends rapidly from the original location with the formation of circumscribed areas and symptoms of fever and disturbance of the general health; such patients sometimes die with the symptoms of general sepsis. If there is destruction of tissue, corresponding ulcers result, generally covered with crusts (lupus exulcerans), which may lead to extensive destruction of the skin and adjoining parts, especially upon the nose, cheeks, lips, etc. (Fig. 367). Very often the process extends at the peripheral portion of the diseased area, while in the centre a smooth or seamed cicatricial tissue develops.

In lupus exulcerans there will be found, in addition to the bacilli, pus cocci, especially the *Staphylococcus pyogenes aur* cording to Leloir and Tave ulcerative changes occurrin are mainly due to the pus c come from without. Cazin hyaline flakes in the connec of ulcerating lupus. They deep stain, with crystal viol ing to Kühne), and are sim bodies found by Russel i liomata. The nodular forr is called lupus hypertroph 368). When there is a ma formation and dilatation the process is called lupus tades. Between these differ there are numerous transit which often occur close t

Fig. 367.—Lupus of the face (Esmarch).

another in the same lupous collection. The clinical course of lupus is usually very chronic. It generally begins in children from four to twelve years of age, or later, and often lasts for many years. In consequence of the losses of substance and marked cicatricial shrinkage or diffuse cicatricial thickening, bad deformities result, particularly on the face, the treatment of which will be discussed in the Regional Surgery. Not infrequently patients with lupus die of tuberculosis of the internal organs—of the lungs, for example. Sometimes epitheliomata originate in lupous foci and cicatrices (Fig. 369).

Fig. 368.—l lupus (Busch

Treatment of Lupus.—The treatment of lupus consists, in addition to a suitably invigorating mode of life (see § 83, Tuberculosis), mainly in adopting energetic local surgical measures, such as excision of the lupous disease or its destruction with the sharp spoon (Volkmann, page 77), the Paquelin thermo-cautery (see page 79), or the galvano-cautery (see page 80). The earlier a lupus is remove pation with the knife the sooner may permanent recovery b The wound from the excision is either simply closed by

if this is impossible on account of too great a loss of substance, the cutaneous defect is remedied by plastic operations (see page 140), or by Thiersch skin grafts (see page 147). The plastic operation or transplantation of skin prevents the troublesome consequences produced by cicatricial contraction, and is especially valuable in preventing recurrences. By excision of the lupus and making use of Thiersch skin grafts, particularly on the face, I have obtained very satisfactory results and have prevented or overcome bad deformities. Punctures made with a galvano-cautery curved at the end, or with the fine tip of the Paquelin cautery, are exceedingly serviceable for the pure macular or exfoliating lupus, such as occurs upon the face. Thayer recommends destruction of lupus by the sun's rays which are concentrated by means of a lens upon the lupous skin-area; the wound resulting from the burn heals quickly and well. The Röntgen rays have been used in the same way. We destroy lupus exulcerans and hypertrophicus by vigorous scraping with the sharp spoon, or by using the Paquelin thermo-cautery, in case excision is impossible. I have given up the use of caustics altogether (caustic potash, copper sulphate, nitric or chromic acid, etc.). Kaczanowski speaks well of cauterization with powdered permanganate of potassium, which is applied to the lupous skin area in a layer two to five millimetres thick. Liebreich recommends the subcutaneous injection of cantharidic acid or of the cantharidate of potassium. The numerous other remedies, chiefly antiseptics, and many of the ointments which have been recommended for the local treatment, are in my experience of little value; permanent cures are rare. In cases, however, that are not adapted to excision pyrogallic acid in ointment form (1 : 10), salicylic-creosote plaster (Unna), Lassar's paste or Unna's mercurial plaster are very useful, particularly after previous scraping with a sharp spoon or puncture with the thermo- or galvano-cautery. The constitutional treatment by strengthening food, good air, sea baths, proper climate, etc., is, next to the energetic local treatment, of the greatest importance, especially for preventing any recurrence of the disease. The treatment of lupus by Koch's tuberculin is described on page 431. Actual cures by tuberculin are rarely obtained. I have never seen

Fig. 369.—Epithelioma of the left orbital region in a lupous patient forty-eight years old.

one. In the course of the treatment, after apparent improvement has occurred in the affected portion of skin, I have excised a piece of the latter and found in the deeper parts, under the healed external cutaneous covering, eruptions of new tubercles.

6. **Ulcers of the Skin.**—By ulceration is understood a granulating defect in the skin accompanied by a suppurative breaking down of the granulations, which shows no tendency to heal. Ulcers present great differences as regards their size, character, and course. The causes of an ulcer, its location, and the general condition of the patient, have a most important bearing upon its clinical course. According to the intensity of the reactive inflammation, we make a distinction between atonic or torpid ulcers and inflammatory ulcers. There are great differences in the shapes of ulcers, some being round, others half-moon-shaped, circular, or irregular in outline. The surface of an ulcer may be smooth or sunken, or more or less prominent. According to the character of the surface of the ulcer or its base we distinguish œdematous, hæmorrhagic, gangrenous, sloughing, and fungous ulcers; the latter are marked by prominent, spongy, inflamed granulations. Very often a canal, or fistula, as it is called, extends from the ulcer to a greater or less depth into the subjacent parts. The fistulæ (from *fistula*, a pipe), as a general thing, originate from some deeply placed focus of inflammation which has gradually made its way to the surface. The edges of an ulcer may be either more or less normal, flat or swollen, or hard and like a wall (callous ulcer), or undermined (sinuous ulcer). Phagedenic ulcers (*φαγέδαινα*, from *φαγεῖν*, to eat) are those which increase more or less rapidly in circumference analogously to the hospital gangrene of wounds (see § 72).

Fig. 370.—Varicose ulcer of the leg (*a*), resulting from varicose veins.

The causes of ulcers are very numerous, and are sometimes local and sometimes constitutional. Ulcers originate from traumatisms of various descriptions, from stasis, or from the suppurative breaking down of tumours and products of inflammation, such as syphilis (§ 84), tuberculosis (§ 83) lupus and leprosy (§ 85). The varicose ulcer of the

leg, of so common occurrence, develops from inflammatory stasis in the leg in conjunction with dilated veins (varices, Fig. 370). When varices exist, any mild inflammation, a slight traumatism, or an eczema vesicle may, as a result of the venous stasis, give rise to an ulcer, since repair, or the formation of normal granulation tissue, is rendered difficult by the disturbance in the circulation. Ulcers may also originate when in any portion of the body a necrosis of the skin is brought about by pressure. In this class belong the bedsores which occur upon the sacrum, over the trochanters, on the heel, etc., in individuals whose nutrition is impaired and whose circulation, as a result of anæmia and cardiac weakness, is imperfect. Trophoneurotic gangrene and ulcerative processes occur in paralytic conditions and other diseases of the nervous system. Great interest attaches to the often multiple, neurotic ulcers of the skin occurring in conjunction with gangrene of the skin, as a result of ascending neuritis with secondary disease of certain central portions of the spinal cord (Doutrelepont, Kopp, and others). The soft and hard chancres have been mentioned in § 84.

Pendjeh Ulcer.—A peculiar ulcer occurs in Pendjeh in the form of a plague, which in the last few years has attacked principally the Russian troops in Transkaspian, more especially in the department of Murghab. In 1885 ninety per cent. of all the troops in this department suffered from the disease. The latter is characterised by the formation of, e. g., twenty to forty to sixty to ninety vesicles and ulcers over the entire body without marked disturbance of the general health. The disease lasts from three to six months —on an average three and a half months. The cause of the ulcers is thought to be a micro-organism occurring in the Murghab water which reaches the human body with the mist and dust and infects the skin. The treatment of the ulcers is the usual one. Subor recommends a five-per-cent. alcoholic solution of methyl-violet, which is painted upon the surface of the ulcer after the latter has been disinfected with bichloride. The ulcers are then left exposed, only the larger ones being covered with gauze and cotton.

Treatment of Ulcers.—The treatment of ulcers varies with their cause. The latter must always be carefully taken into account if an ulcer is to be properly treated; for example, a constitutional dyscrasia, like syphilis, tuberculosis, or bad nutrition, nervous diseases, etc., must at the same time be attended to. The treatment of every ulcer should be conducted upon antiseptic principles. Dressings with iodoform, dermatol, oxide of zinc, bismuth, naphthaline, with or without ointments (boric-acid ointment), are excellent. The numerous antiseptic materials for covering a wound (powder, ointments, etc.) are enumerated in §§ 45, 46. Gangrenous phagedenic ulcers are best treated by scraping them with a sharp spoon, by cauterisation with caustic potash, the Paquelin or galvano-cautery. In large ulcers the use of perma-

nent irrigation (page 181), or a bath for the entire body (page 182), are sometimes advantageous. It is very important to prevent any stasis, any disturbance of circulation, by placing the parts in a suitable position, by rest, etc. In varicose ulcers of the leg, satisfactory results are often obtained by enveloping the leg in Martin's elastic bandage, which possesses the great advantages of not confining the patient to bed and of allowing him to attend to his business. Not infrequently, however, Martin's elastic bandage is not well borne, as it excites a persistent eczema, which should be treated as described on page 528. If the borders of the ulcer are slightly movable, *circumcision* of the ulcer is an excellent means of making it possible for the base of the ulcer to contract, thus hastening the healing (Nussbaum). The circumcision is performed by carrying an incision through the skin down to the fascia, around the ulcer some one to two to three centimetres from its edge. A very good method of treatment of varicose ulcers of the leg consists in ligation of the internal saphenous vein on the inner side of the thigh about a hand's breadth above the internal condyle of the femur, with or without circumcision of the ulcer (Trendelenburg. Perthes reported sixty-three cases of varicose veins of the leg which were treated in this way, among which were fifty-four ulcers of the leg; the latter healed in most cases soon after the operation. For hastening the growth of skin over the ulcer, Thiersch's method of skin grafting (§ 42) is particularly serviceable after previously freshening or scraping off the base of the ulcer with a sharp spoon. Circumcision of the ulcer can be combined to good advantage with skin grafting. The latter procedure has taken the place of the implantation of skin flaps with pedicles taken from immediately adjoining or distant portions of the body, and which were formerly much in vogue. Maas in particular has obtained good results from the implantation of pedunculated skin flaps taken from a distant portion of the body. He recommends that the flap to be transplanted be cut as much as possible in the direction of the course of the vessels, and, after previously removing the layer of granulations in the defect with a sharp spoon, the edges of the ulcer should be freshened all around; the flap is then united by sutures to the borders of the defect and by buried sutures to its surface. The wounded and exposed portion of the flap is prevented from drying by being covered with a plentiful amount of boric-acid ointment spread on gauze. An antiseptic dressing is placed over everything, and the portions of the body under treatment are completely immobilised by a plaster-of-Paris dressing. Whenever possible, the dressing is left undisturbed for fourteen days and then the pedicle of the flap is divided. In this way a flap can be transplanted

from the breast to the arm, from one leg to the other, and from the upper extremity to the face, and joints can thus be made movable which were previously stiffened by cicatricial contractures—i. e., had lost their function. In conclusion, I should mention that hypertrophic bone under the base of an ulcer—in the tibia, for example—must be carefully levelled off with the chisel; any undermined borders around an ulcer should be excised, fistulæ should be laid open, etc. In many cases of extensive ulceration, when repair is impossible or the affected limb is useless, amputation may be indicated. It should be borne in mind that, as a result of the exposure and erosion of a vessel by an ulcer, a serious or even fatal hæmorrhage may occur, unless aid can be speedily obtained.

Scurvy (Scorbutus) and the Ulcers which occur with it.—Ulcers also occur in scurvy, especially on the gums, in the upper portion of the cavity of the mouth, and on the lips. The gums swell as a result of hæmorrhages, become bluish red, and then break down into peculiar bluish-red ulcers with bluish-green borders and granulations, which bleed easily. In other respects scurvy is characterised by hæmorrhages into the skin and the subcutaneous cellular tissue (purpura scorbutica), into the muscles, joints, and from the intestine, by general emaciation, anæmia, and hydræmia. Scorbutus now occurs less often than formerly. It is to be regarded essentially as a severe cachexia, or a general disturbance of nutrition, involving particularly the walls of the blood-vessels. Whether micro-organisms play any part in the origin of scurvy is still a matter of uncertainty. The disease occurs endemically, especially among individuals who live under unfavourable external conditions, such as sailors who have eaten for a long time only salted meat without any fresh vegetable food. It also occurs in damp, badly ventilated and crowded quarters (prisons, barracks, etc.). Scorbutus has only a slight interest for the surgeon, so that we must refer the reader to the text-books on internal medicine. The prognosis of this affection, which for the most part runs a chronic course, depends upon the possibility of speedily removing the unfavourable hygienic conditions. Hence the treatment consists mainly in providing good dwellings and good food (fresh meat, fresh vegetables). In addition to this, acids—particularly vegetable acids—are beneficial in the form of fresh watercress and sorrel. Since legislation has provided that ships, prisons, etc., should be well supplied with food, and that the inmates of prisons obtain fresh vegetables in sufficient quantity, scurvy has become less common. The ulcers in the mouth should be treated by mild cauterisation with nitrate of silver, iodoform, and gargles of three per cent. chlorate of potash or boric acid.

Other Anomalies of Granulating Wounds.—In addition to the ulcerative destruction of granulations there are still other anomalies of granulating wounds which interfere with their healing, and these we shall discuss briefly. By fungous or spongy granulations are understood those which project above the level of the surface of the wound in the form of a fungus. Soft exuberant granulations like these are observed in tuberculosis especially, and also when there are any hindrances to healing, such as those due to induration of

the surrounding parts, or to the presence of a foreign body, or a necrotic piece of bone—a sequestrum, as it is called—in the depths of the wound. The treatment of these fungous granulations consists in removing the above-mentioned causes and in applying energetic cauterisation with the nitrate-of-silver stick. Pressure also does good service. When necessary, the granulations may be removed by a sharp spoon, the thermo-cautery, or simply by the knife or scissors, and the wound surface covered with very small pieces of skin by Thiersch's method (§ 42).

Irritable Ulcer.—By *irritable* ulcer very painful granulations are meant, which bleed easily. It is not known upon what the painfulness of these granulations really depends, and it is the more remarkable from the fact that granulation tissue usually possesses no nerves. The affection is observed most commonly in anæmic or hysterical individuals. The best treatment consists in the application of desiccating powder dressings (iodoform, bismuth, dermatol), or in the removal of the painful granulations by caustics, or, better, with scissors or the sharp spoon, followed by transplantation of skin, etc.

7. **Elephantiasis.**—By elephantiasis (elephantiasis Arabum or pachydermia acquisita) is understood an extensive hyperplastic thickening of the skin and subcutaneous cellular tissue over large portions of the body, most frequently observed upon the lower extremities and genitals (Fig. 371). The hyperplasia of the tissues may develop in conjunction with various chronic and frequently recurring inflammations, such as chronic eczema, ulcerations, chronic periostitis and osteomyelitis, erysipelatous and lymphangitic processes, lymph stasis, injuries to nerves, etc. A second form of elephantiasis is the result of a chronic affection, the nature of which is still unknown, and occurs endemically in tropical and subtropical countries (Central America, Arabia, India), while in Europe only sporadic cases are observed. In its epidemic form the process is due in many instances to the presence of the filaria Bancrofti (or medinensis), which, with its embryos, inhabits the lymphatic vessels and causes lymph stases and inflammations, particularly of the external genitals, the thigh, and peri-

Fig. 371.—Elephantiasis in a native of Samoa; removal of the scrotum, which weighed seventy-eight pounds, followed by recovery (Königer).

toneal cavity. The invasion of the filaria does not in every case give rise to elephantiasis, and as a matter of fact the parasites have not been found in the majority of cases. The thread-like worm is 8 to 10 centimetres long, and its larvæ about 0.35 millimetres. They probably enter the human organism, the lymphatic vessels, and the blood from the intestine (Manson, Scheube).

The portions of skin involved in the elephantiasis are sometimes dense and hard (elephantiasis dura) and sometimes made up of soft, greyish-white tissue (elephantiasis mollis), and often contain greatly dilated lymphatic vessels (elephantiasis lymphangiectatica). Elephantiasis is occasionally congenital, and may be a result of abnormal development and new formation of blood and lymphatic vessels (elephantiasis congenita telangiectodes and E. lymphangiectodes). (See also Tumours.) In rare instances an inherited elephantiasis is observed. Some forms of tumours, such as the soft diffuse fibromata, neurofibromata, and plexiform neuromata, may resemble a circumscribed elephantiasis.

Treatment of Elephantiasis.—The treatment of elephantiasis in the beginning of the disease is directed towards the cause, particularly the inflammatory changes in the affected portions of the body. Enveloping the parts in elastic bandages, placing them in an elevated position, injections of alcohol, ligation of the main afferent artery, punctate cauterisation, repeated spindle-shaped excisions, and total removal of an elephantiatic scrotum or of the affected extremities by amputation or disarticulation, have all been employed (see Regional Surgery).

Myxœdema (see also Regional Surgery).—Myxœdema is a well-characterised disease of great pathological interest which is much more common in some countries than in others. It has been studied chiefly by Gull, Ord, Virchow, Horsley, Eiselsberg, Ewald, and others. There have been differentiated an idiopathic, a post-operative, and an infantile form (sporadic cretinism). The disease, which was first described by Gull in 1873 as the "cretinoid condition," affects women more often than men, especially those of middle age. There is always a destructive change, such as fibroid degeneration, interstitial connective-tissue development, or other disease of the thyroid gland, the latter being sometimes enlarged and sometimes atrophic. Myxœdema has also been observed in connection with syphilitic disease of the thyroid gland. The interstitial connective-tissue growth generally present in the thyroid is mainly the result of an inflammatory process, and is also very frequently found in the skin and in the internal organs. A pronounced excess of mucin is found in the skin and blood; the amount of hæmoglobin in the blood is diminished, while the amount of red

corpuscles and fibrin varies, being sometimes diminished and sometimes increased. The power of the red blood-corpuscles to take up oxygen may be greatly diminished. The skin, particularly of the face and extremities, is characteristically swollen. There are also disturbances of speech, of motion, and of intellect, and, in brief, a remarkable decline of the bodily and mental functions. In youthful individuals the normal development does not take place (dwarfs, etc.). Myxœdema is extremely rare in childhood. I observed a case in a boy three years of age due to congenital absence of the thyroid gland.

By experimental extirpation of the thyroid gland in animals, and by its total extirpation in man, there is produced a form of disease, the so-called cachexia strumipriva or thyreopriva, which corresponds in all respects to myxœdema, and hence only a *partial* removal of the thyroid gland is allowable in man. Myxœdema has also been observed after partial extirpation of the degenerated gland when the retained portion atrophied with remarkable rapidity (Köhler). Sometimes myxœdema takes several years to develop after removal of a goitre. Seldowitsch observed myxœdema after removal of an accessory gland at the base of the tongue (see also Regional Surgery). Schiff and Eiselsberg demonstrated that animals withstand total extirpation of the thyroid gland if their own thyroid gland, or one taken from another animal of the same species, is successfully implanted in the peritoneal cavity and resumes its normal function there. The function of the thyroid gland, which is to prevent the accumulation in the body of mucin, is disturbed in myxœdema. Therefore myxœdema may originate from operative removal as well as from degeneration of the thyroid gland, and is probably identical with the so-called sporadic cretinism which occurs in children, and is closely related to endemic cretinism. The course is usually chronic, but sometimes acute. The prognosis was at one time very unfavourable, the disease usually terminating by death in a few years, sometimes with tetanic manifestations. In recent times improvement and even cures have taken place after the internal administration of the thyroid gland of sheep and calves.

Treatment.—The best treatment consists in the administration of the thyroid-gland material from sheep and calves. Caution is, however, necessary, as symptoms of poisoning (collapse, rapid pulse, cardiac weakness, Graves's disease, etc.) have been observed. The use of the fresh thyroid gland is much less often followed by symptoms of poisoning than is the administration of the various preparations of the dried gland. The thyroid-feeding is continued as long as possible, and small doses should be used at first. The gland has also been used with success in cases of obesity and different skin diseases. In the

s about ten grammes of the fresh gland are given weekly, 'en about five grammes. The fat and outer fibrous capsule in as aseptic a manner as possible, the gland is cut into spread on bread, and seasoned with salt and pepper. 'oid tablets may also be employed. In extreme cases the of a fresh functionating thyroid gland into the abdominal e tried (Eiselsberg). For further particulars see Regional itre, Graves's Disease, etc.).

na.—By scleroderma is understood a circumscribed or more dif- ıg of the skin, occurring rather suddenly in adults, without es, and either remaining stationary or gradually extending, and ıating in atro- eroderma the l as wood, and ccurs on the e, and the ex- s nature is un- omically, Chi- ickening of the a of the skin places with an ith leucocytes. y in the main inflammation. in one case an f the thoracic reatment con- ge, baths, soft- s, and plenty xercise (gym- ing, running,

ma neonato- ıg to Langer, is stiffening and f the subcuta- r tissue in con- lapse and low- ıperature.

c Atrophy of diopathic atro- in is an exceed-

Fig. 372.—Ichthyosis (Byrom Bramwell).

isease, and the etiology is obscure. Sometimes excessive cold ous influences, etc., appear to be the cause. The atrophic areas ·ly increase in circumference, and eventually lead to corre- figurements. As yet it has been impossible to find a success- t.

Dermatolysis.—In the so-called dermatolysis (Tilbury, Fox), the skin without apparent change in structure, becomes too abundant and loose, giving rise to folds. The faces of youthful individuals may thus assume an aged expression. The elasticity of the skin is sometimes very marked; the skin of the chest may, for example, be drawn up as far as the eyes.

Ichthyosis (from ἰχθύς, fish) is usually a congenital, scale-like thickening of the epidermis involving generally the entire body (Fig. 372).

Hystricismus (from ὕστριξ, swine's bristle) is also a congenital disease and consists in the formation of growths on the skin resembling thorns, and results from hypertrophy of the papillæ and epidermis.

Mycosis fungoides (μύχης, fungus, sponge, εἶδος, shape, form) is a very interesting disease which begins by the formation of spots either isolated or confluent, which resemble sometimes urticaria and sometimes psoriasis or eczema. Fungous tumours of semi-soft consistency are then gradually formed in various places on the body; these break down and disappear completely, leaving behind brownish or greenish crusts. With the repeated formation of new tumours the patient gradually succumbs to an increasing cachexia, accompanied usually by a profuse diarrhœa. The new growths belong probably to the granulation tumours. It is possibly an infectious disease caused by micro-organisms. The treatment is symptomatic.

Emphysema—i. e., a collection of air in the skin and subcutaneous tissue—is observed most frequently after injuries of the larynx, trachea, and lungs. There can be felt in such cases characteristic soft crepitating swellings. Emphysema may gradually spread over the entire body (see Regional Surgery).

For tumours of the skin, see Tumours, §§ 125 to 130.

§ 94. **Inflammations and Surgical Diseases of the Mucous Membranes**—*Diseases of Mucous Membranes of Surgical Importance.*—Brief mention will be made here only of those diseases and inflammations of mucous membranes which are the object of surgical treatment. We shall discuss injuries in Regional Surgery. As a general rule, wounds of mucous membrane, if strict asepsis is observed, heal readily, particularly under the use of iodoform.

Acute Inflammation.—Acute inflammation of the mucous membranes occurs as an acute catarrh or acute catarrhal inflammation which is characterised by hyperæmia, œdematous swelling, and the formation of a discharge at first poor in cells and then containing large quantities of them. Some of the cells are extravasated colourless blood-corpuscles, and others desquamated epithelium. Not infrequently in catarrh there is a development of vesicles and superficial losses of substances—catarrhal ulcers. The causes of catarrhs may be mechanical or chemical in nature, or, what is most common, they may be due, in the main, to micro-organisms, as is, for instance, the acute catarrh of the mucous membrane of the genitals—gonorrhœa (see page 444). Catarrhs which occur as a result of chemical irritations are produced, for example, by

the action of mercury or iodine; many individuals are very susceptible to these two substances. The acute inflammations which follow the use of mercury and attack the cavity of the mouth (stomatitis mercurialis), are occasionally observed during the treatment of a wound with bichloride, or during the inunction treatment of syphilis, etc. (see page 445). Mercurial stomatitis is characterised by a swelling of the gums, salivation, swelling of the mucous membrane of the mouth at various points, and the formation of ulcers. Mercurial stomatitis, as we shall see, is best prevented by cautious use of bichloride in the treatment of wounds, by paying careful attention to the cleanliness of the mouth, by stopping smoking during the inunction treatment, etc. The treatment of the mercurial stomatitis itself consists in gargling with chlorate of potash or boric acid. This complication can usually be speedily cured by superficial cauterisation of the ulcers with silver nitrate or copper sulphate in substance, and also by stopping the bichloride dressings or the inunctions.

FIG. 373.—Croupous membrane (*B*) upon a mucous membrane (*Sch*), consisting of a network of fibrin which is filled with leucocytes. × 150.

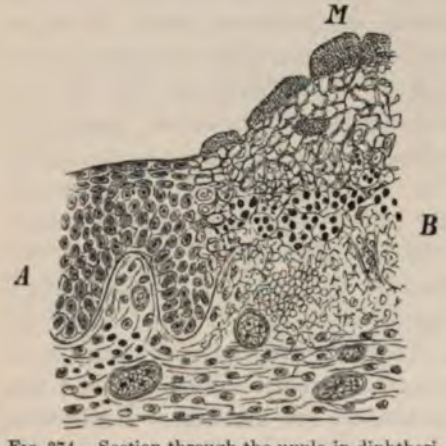

FIG. 374.—Section through the uvula in diphtheritis faucium at the border of the healthy tissue: *A*, normal epithelium and submucous tissue; *B*, the connective tissue underneath the epithelium and mucous membrane infiltrated with fibrin, leucocytes, and red blood-corpuscles; *M*, masses of micrococci. × 120.

Cancrum oris or *noma* is a severe ulcerative stomatitis, which will be discussed in Regional Surgery, with the other diseases of the mucous membranes in the facial cavities, the digestive tract, genito-urinary apparatus, etc.

Croupous and Diphtheritic Inflammation. — By *croup* and *diphtheria* inflammatory processes are understood which are for the most part identical pathologically and clinically, and only differ in degree. Both inflammations are characterised by the formation of an inflammatory product consisting of fibrin and cells, which is slightly adherent to the surface of the

mucous membrane. In croup (Fig. 373) the membrane lies *upon* the mucous membrane, while in diphtheria the exudate is also found *in* the mucous membrane, and the latter becomes more or less necrotic (Fig. 374). In the formation of this pseudo-membrane, according to Baumgarten, the "fibrinoid" degeneration of the epithelium plays an important part as well as the fibrinous exudate. In croup there is a fibrinoid degeneration of the epithelium only, but in diphtheria this process also involves the connective tissue. The local death of tissue produced by the diphtheritic inflammation is, according to Cohnheim and Weigert, a coagulation necrosis—i. e., a death of the tissues and cells due to the coagulation of lymph which permeates the affected tissues and penetrates into the cells. The croupous and diphtheritic membranes come away after a certain length of time, being cast off by the new epithelium which is produced underneath and pushes the remains of the membrane before it; in severe cases the membrane comes away *in toto*. In extensive croup of the bronchi the latter are filled, in severe cases, with a fibrinous exudate, so that there is marked dyspnœa, and the patient coughs up branched masses of fibrin corresponding to the bronchi (Fig. 375). Croup can be excited experimentally by the injection of liq. ammonii caustici into the trachea of a rabbit, the animals usually dying in two to three to four days with symptoms of asphyxia. There is no *anatomical* distinction between this experimental croup and epidemic diphtheria (Middeldorpf, Goldmann). The pharynx and trachea are most frequently affected by the croupous and diphtheritic inflammation; less often the mucous membrane of the bladder and intestine. Diphtheria occasionally occurs in the skin, starting, for example, from infection through a cutaneous abrasion or wound, especially in the neighbourhood of mucous membranes such as that of the female genital tract, the rectum, etc. True diphtheria is an infectious disease which is produced by a specific bacillus discovered by Löffler, and is to be carefully distinguished from all other pathological processes which are likewise accompanied by the formation of croupous or diphtheritic changes in the mucous membranes and do not differ *anatomically* from true diphtheria (so-called pseudo-diphtheria). By temporarily interrupting

Fig. 375.—Branching mass of fibrin in bronchial croup.

the circulation of blood in the urinary bladder Heubner excited artificially a local pseudo-diphtheria of this description which was not transmissible to animals by inoculation like true diphtheria. In every case of suspected diphtheria a bacteriological examination should be made for the detection of the Löffler bacillus. In true diphtheria there develops, as a result of the absorption of the poisonous products of the bacterial metabolism, a febrile systemic intoxication the severity of which varies greatly, though it very often speedily terminates in death, particularly when a degeneration of the muscles of the heart takes place. Another important cause of death consists in extension of the inflammation to the lungs. Among further sequelæ of diphtheria, nephritis (albuminuria) and paralyses are especially prominent. Baginsky has observed in rare cases the development of tetanic symptoms (trismus and tetanus). The symptomatology of diphtheria is discussed in Regional Surgery. See also Wound Diphtheria, § 72.

The Etiology of Diphtheria—Löffler's Diphtheria Bacillus.—Löffler was the first to prove the constant presence of a species of bacteria in human diphtheria; he cultivated it artificially and inoculated animals with it. It was impossible to excite genuine diphtheria in animals, but Löffler was able to prove that the bacteria in question had pronounced poisonous properties. Fränkel and others have confirmed Löffler's statements, and Roux and others successfully inoculated animals with Löffler's bacillus and observed the symptoms which are peculiar to human diphtheria, particularly the formation of local diphtheritic processes and the paralyses which follow the general intoxication. Upon the basis of these facts, we are justified in the belief that Löffler's bacillus is the actual excitant of diphtheria.

The diphtheria bacilli are small rods about as long as tubercle bacilli, though almost twice as thick, of a plump appearance, and generally with rounded ends (Fig. 376). They vary, however, greatly in their form, the rods having frequently a club-shaped thickening at the end, while others are in process of division into several pieces by transverse segmentation (manifestations of involution). The bacilli are found in the diphtheritic pseudo-membrane, and nowhere else in the body; consequently the severe constitutional symptoms of diphtheria are caused by the exceedingly poisonous products of their metabolism. Opinions vary as regards the nature of the toxines of the diphtheria bacilli, though they are generally considered to be albuminoid bodies belonging, according to Brieger and Fränkel, to the toxalbumens, according to Roux and Yersin to the diastases, and according to Gamaleia to the nuclein compounds. They are formed either by the decomposition of the albuminous bodies contained in the nutritive substances, or the microbes develop them within themselves by synthesis of simpler bodies (Guinochet, Strauss). The toxic substances of the diphtheria bacilli are marked by a certain instability being destroyed by heat and ferments (pepsin, pancreatin), and passing through the digestive tract without causing any disturbance (Gamaleia). The diphtheritic poison is decidedly weakened

by antipyrine (Vianna). Mixed (septic) infections originate from the presence at the same time of streptococci and staphylococci.

The bacilli are facultative anaërobic, and incapable of movement; they grow at temperatures ranging between 68° and 104° F. upon gelatine or other nutritive medium, which must always be made slightly alkaline, and especially well upon Löffler's blood serum (three parts blood serum from cattle or sheep, one part beef bouillon, one per cent. peptone, one half per cent. common salt, one per cent. grape sugar) and upon glycerine-agar. On Löffler's blood serum a thick, glistening, whitish scum forms in the incubator at a temperature of 98.4° F. in about two days. On glycerine-agar at the incubator temperature, flat, greyish-white, glistening colonies, with smooth edges, the size of a millet seed, develop within twenty-four to forty-eight hours (Fig. 377). On agar the cultures at first grow slowly, but the second generation more luxuriantly, as the bacilli have then become accustomed to the nutritive medium, which was not at first suited to them. But at the

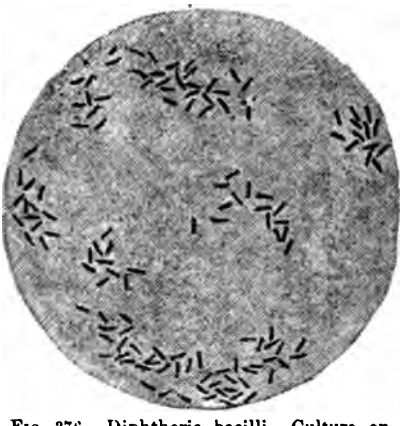

Fig. 376.—Diphtheria bacilli. Culture on coagulated blood serum. × 1,000.

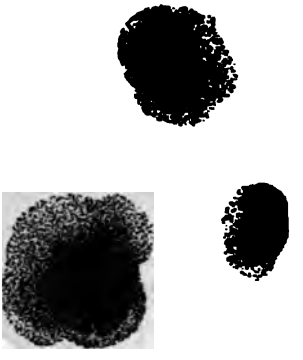

Fig. 377.—Diphtheria bacilli. Colony on agar twenty-four hours old; unstained. × 100.

same time they suffer a loss in virulence. When stab cultures are made in gelatine, small white globular colonies develop along the inoculated line of puncture. On gelatine plates, at a temperature of 22° to 24° C. (71° to 75° F.), the colonies remain small and the gelatine is not liquefied. The bacillus grows upon potatoes, provided the surface is made alkaline; milk is also an excellent nutritive medium. At temperatures ranging from 45° to 50° C. (113° to 122° F.) the bacilli perish. Spore formation has not been observed. The bacilli are also possessed of great powers of resistance; they will remain in a dried pseudo-membrane and be capable of development after the lapse of three to four months. Roux and Yersin demonstrated that serum cultures, under ordinary conditions, retain their vitality and virulence for five months; and, furthermore, that the cultures kept entirely shut off from the action of air and light still possess their full virulence after the lapse of thirteen months.

The diphtheria bacilli can be best stained with Löffler's alkaline methyl-blue solution; they do not stain by Gram's method. But, according to the

recent investigations of Roux and Yersin, the latter method can also be easily used. The virulent diphtheria bacilli are almost never found in the mucus of the mouth of a man who is healthy or who has some other disease, but Löffler and Hofmann state that pseudo-diphtheria bacilli are often found which are very similar but have no pathogenic action, and are to be regarded as possibly weakened forms of the diphtheria bacilli.

Transmission of Diphtheria to Animals.—Inoculations in animals are often unsuccessful; guinea-pigs, rabbits, doves, and chickens are particularly susceptible, while mice and rats are not very much so. In guinea-pigs, doves, etc., the cultures excite pseudo-membranes in the trachea, and sometimes severe constitutional symptoms, paralyses, etc. Guinea-pigs are the most susceptible; within a few days after subcutaneous inoculation they die with œdema, pleuritic effusions, etc., but the bacilli are not found in the internal organs. Filtered cultures, or the poisonous albuminous bodies (toxalbumens) isolated from the cultures excite severe symptoms of intoxication, which, however, take a long time to cause death.

Artificially Acquired Immunity from Infection by Diphtheria.—Behring and Kitasato have made animals artificially immune from diphtheria (1) by the use of cultures sterilised by Fränkel's method; (2) by the addition of iodoform to the cultures; (3) by subcutaneous and intra-abdominal injection of the pleuritic exudate which frequently forms in diphtheritic animals; (4) by subcutaneous injection of iodoform very soon or a few hours after the infection with diphtheria. It is also possible to give animals an increased power of resistance against diphtheritic infection by the administration of peroxide of hydrogen for a few days before the infection. By inoculating guinea-pigs with sterilised culture fluids heated for a few hours to between 60° and 70° C. (140° and 168° F.), C. Fränkel obtained immunity after the lapse of fourteen days. Two kinds of substances are found in the culture fluids of diphtheria bacilli, viz., a toxic substance which is destroyed when heated to 55° to 60° C. (131° to 140° F.), and an immunising substance. According to Behring and Kitasato, the animals which have been rendered immune are not only protected from infection with living diphtheria bacilli, but also from the injurious effects of the poisonous products of their metabolism. Nevertheless, the immunity may be again lost by repeated injections of considerable amounts of poison, especially if the immunity has not been sufficiently firmly established. The artificially acquired immunity to diphtheritic infection depends upon changes in the blood serum of the animal—i. e., upon the presence of specific protective substances (antitoxines) which act only upon the diphtheritic poison and not upon other poisons. The blood serum of animals (horses) rendered immune to diphtheria is consequently used in the form of hypodermic injections in the treatment of diphtheria. Since the introduction of this antitoxine treatment of diphtheria the mortality of the latter has diminished. The earlier it is used the more efficient is its action. The latter consists either in a direct influence upon the diphtheritic poison or in a strengthening of the curative powers of the organism—in other words, an increase in its power of resistance. The antitoxic serum can also be used to advantage in a prophylactic way to protect those in the vicinity of the patient from infection. This immunising action of the antitoxic serum may last, according to Heubner, only three

weeks, so that in a prolonged epidemic it would be necessary to repeat the injection from time to time.

Spread of Diphtheria.—The bacillus of diphtheria varies in the degree of its virulency at different times. This explains why the course of diphtheria in different cases and in different epidemics is so dissimilar. Diphtheria spreads by contagion; the membranes which are coughed up, the sputa and the saliva, are the most common sources of infection. During convalescence the bacilli remain alive in the mouth for about three weeks; in a dried condition they may persist in thick layers for three to four months, and in a half-dried condition for seven months. Toys, eating and drinking utensils, kissing, etc., sometimes cause the spread of the disease. An ectogenous development of diphtheria bacilli sometimes takes place in articles of food, such as milk. The individual predisposition to diphtheria decreases very much after the thirteenth year. A pharyngeal mucous membrane affected with or having a tendency to catarrh is a favourable soil for the lodgment of the diphtheria bacillus. To prevent the starting and spread of diphtheria, the patients should first of all be strictly isolated in every respect, and objects coming in contact with them should be properly disinfected. Furthermore, the healthy individuals living with the patient should be injected with antitoxic serum.

Other Bacteria Streptococci and Staphylococci present in Diphtheria.—In addition to the diphtheria bacilli there are very frequently—in fact almost always—found streptococci. These appear to have no bearing upon the diphtheria as such, but may give rise to general septic infection—mixed infection (Beck, Barbier, etc.). But, according to Baginsky, there is a form of diphtheria which clinically is like true diphtheria, but is not dangerous, and terminates in recovery; in this Löffler's bacillus is not present, and Baginsky only found streptococci and staphylococci.

The Pseudo-Diphtheria Bacillus.—In addition to the diphtheria bacillus, which is the excitant of true diphtheria, Löffler and others have described a pseudo-diphtheria bacillus which is morphologically and biologically slightly different from the true diphtheria bacillus. It is somewhat shorter and thicker, grows luxuriantly at a temperature of 20° to 22° C. (68° to 72° F.) in bouillon, and changes the reaction of bouillon more rapidly, forms upon serum a more yellow scum, and does not thrive as well in the absence of air as the true diphtheria bacillus. When inoculated in animals, local manifestations are sometimes observed, but death never occurs (Roux, Yersin). The pseudo-diphtheria bacillus is found in the mouths of healthy individuals and in simple sore throats. According to Roux and Yersin, a certain relationship exists between the two kinds of bacilli. They succeeded in permanently changing very virulent true diphtheria bacilli, by the action for several days of a steady stream of air, to such an extent that they behaved like pseudo-diphtheria bacilli; and on the other hand, by simultaneous inoculations with erysipelas cocci, they were able to restore to the weakened diphtheria bacilli their full virulence, but not to the pseudo-diphtheria bacilli. More recent investigations make it seem probable that the two bacilli, the true diphtheria bacillus and the pseudo-diphtheria bacillus, are not different micro-organisms, but belong to the same species and are merely of different virulence (Löffler, Fränkel, Hofmann, Roux, and others).

§ 95. **Inflammations and Diseases of Blood-vessels.**—The acute inflammations of the arteries and veins—arteritis and phlebitis—have been described in § 69 and § 75 (pyæmia); and the various changes which thrombi undergo, including the cicatricial closure of a vessel, the so-called organisation of a thrombus, were discussed in § 61. There remains for us to take up chronic inflammations of the walls of the vessels, as well as aneurisms and varicose veins.

Chronic Inflammations of the Walls of the Vessels.—The fatty, amyloid, and hyaline degenerative changes occurring in vessels belong more to the domain of pathological anatomy, but hypertrophic conditions in the arteries have also a surgical importance. The development of the collateral circulation after occlusion of a vessel or the formation of an aneurysma racemosum (see Aneurisms) depends upon a hyperplasia of all the arterial coats. Chronic endarteritis is particularly important; it consists in a hypertrophy of the intima from a circumscribed or more diffuse growth of connective tissue. In this class belong endarteritis obliterans, endarteritis deformans, and arteriosclerosis or atheroma. These chronic inflammations of the walls of blood-vessels with thickening and hardening of the same occur in various diseased conditions—e. g., syphilis, nervous diseases, diabetes, alcoholism, lead-poisoning and other kinds of poisoning, and also as a sign of disturbance of nutrition in old age. Nodular or more diffuse thickenings of the arteries develop from inflammations in the parts surrounding the arteries—in other words, from periarteritis. Phlebitis hyperplastica and periphlebitis chronica are much rarer than chronic arteritis, and the pathological changes are not by any means so pronounced.

Endarteritis Obliterans.—The endarteritis of syphilis was first accurately described by Heubner; it occurs either independently and by itself, or within a focus of syphilitic inflammation. The process begins with a cellular infiltration of the intima, which subsequently changes into connective tissue; the media remains more or less intact, or likewise changes into fibrous tissue. The thickening of the walls of the vessels in syphilis is not infrequently very considerable, and the lumen of the arteries may not only be narrowed, but even completely closed. The syphilitic inflammation also occurs in the intima of the veins. As Friedländer in particular has pointed out, there occurs not only in syphilis, but also in various other chronic inflammatory conditions, an obliterating endarteritis from proliferation of the endothelium of the larger arteries as well, which, when it affects an extremity, may threaten the integrity of the whole limb. Riedel observed gangrene of the leg following a circumscribed obliterating endarteritis of the femoral artery in a woman thirty-six years of age. Circumscribed or more diffuse infiltrations of the walls of the vessels are also produced by tubercular inflammation.

Congenital stenosis of the aorta (Morgani, Virchow, Fräntzel, etc.) is matter of more consequence to the physician.

Sclerosis or Atheroma of the Vessels.—Atheroma of the arteries (arte- sclerosis) is mainly a disease of old age, and is particularly apt to follow t habitual use of alcohol. It consists of thickenings of the intima, which occu in patches. The thickened parts, especially at the outset, are soft and jelly-like, or dense and fibrous, or more cartilaginous in character. The atheromatous patches often become calcified, or the tissue may break down and give rise to losses of substance (atheromatous ulceration). Atheroma may occur in all parts of the arterial system, from the valves of the aorta to the smallest arteries, and is sometimes developed to an extreme degree. Atheroma of the veins is more rare, and never of as high a grade. It is essentially an endarteritis which begins with inflammatory infiltration, and leads to a new formation of connective tissue. This is followed by retrogressive changes (fatty degeneration, necrosis, calcification). As a result of arterio-sclerosis there occur a thickening, narrowing, or occlusion of the vessels, with secondary disturbances, and finally necrosis of the parts supplied by the affected vessel, as in senile gangrene (see Regional Surgery). On the other hand, dilatation and rupture of the walls of the artery occur if the media also degenerates and loses its power of resistance. Neurotic angiosclerosis is a special form resulting from injuries and diseases of the nervous system (tabes, progressive paralysis, neuritis, syringomyelia, etc.) and occurring at any age. It leads to thickening of the walls of arteries and veins, at first from hypertrophy of the media and later of the intima, followed by marked narrowing of the vessels and corresponding disturbances of nutrition or necrosis of the tissues.

Aneurisms.—By aneurism is understood a dilatation of an artery filled with flowing blood. The dilatation is either limited to a certain portion of the artery (Fig. 378), or there is an expansion of a whole group of arterial branches and of capillaries with a simultaneous hypertrophy of their walls (Fig. 383). The latter form of aneurism is called aneurysma racemosum or anastomoticum.

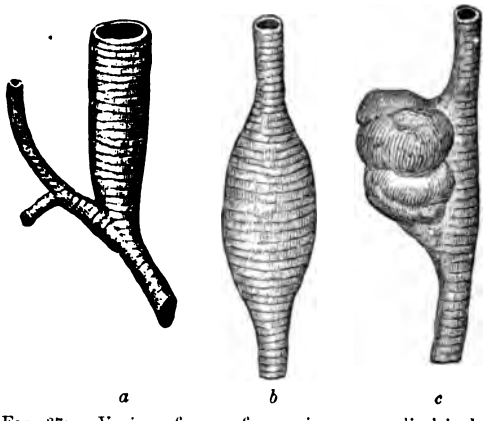

FIG. 378.—Various forms of aneurisms: *a*, cylindrical; *b*, spindle-shaped; *c*, sacculated aneurism.

Aneurisms originate either from injuries or from gradual dilatation of the vessel as a result of disease of its wall, especially chronic endarteritis (atheromatous, syphilitic endarteritis), and periarteritis with secondary atrophy of the wall, particularly the media. Köhler saw a large axillary aneurism

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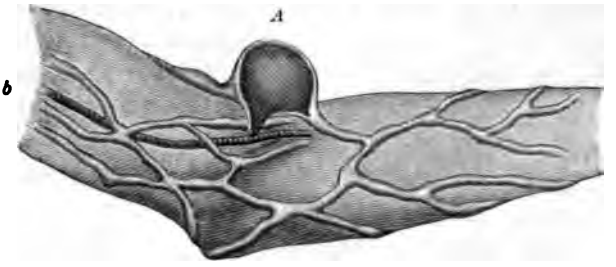
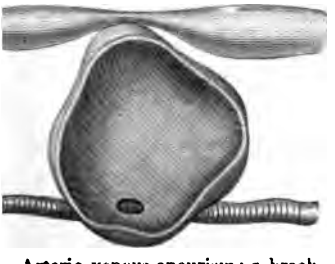


FIG. 379.—Arterio-venous aneurism (*A*) at the bend of the elbow, resulting from a venesection (Bell). The aneurismal sac *A* is cut open (Froriep).

matory processes in the media; but Recklinghausen, Manchot,
hers insist chiefly upon the presence of primary ruptures of the
due to some traumatism, and a marked elevation of the blood
re following, for example, some violent exertion; by these in-
influences the powers of resistance possessed by the arterial
re lessened. An embolus lodging in a branch of an artery may
use an aneurism—for example, calcified endocarditic vegeta-
may bore their way into the wall of an artery, possibly in
in, and erode it, causing it
e way and dilate—embolic
sms (Ponfick). Moreover,
sms may occasionally result
emboli of a suppurative or
character with secondary



—Arterio-venous aneurism: *a*, brach-
rtery; *b*, vena mediana. The sac of
aneurism which communicates with
rtery and vein is cut open (Dorsey).

FIG. 381.—Arterio-venous aneurism of the temporal artery and vein following an incised wound received twenty-five years before (Czerny).

is of the wall of the vessel following endarteritis or periarteritis
y, etc.). All aneurisms developing from a gradual dilatation of
coats of the vessel used to be called *true* aneurisms (aneurysma

vera), in contradistinction to the traumatic aneurisms, which were designated as *false* (aneurysma spuria), from the fact that their walls do not consist of all three arterial coats. This distinction is an artificial one and incorrect. Traumatic aneurisms from a punctured injury, for example, are brought about by a gradual yielding of the thrombus in the wall of the vessel and of the surrounding cellular connective tissue, as a result of the intra-arterial pressure. A sac thus finally develops, the walls of which are made up of the outermost layers of the thrombus, the surrounding soft parts, and new-formed connective tissue. In the so-called true aneurism the vessel dilates very gradually, as a result of chronic endarteritis, and according as the latter involves the entire circumference of the artery or only a portion of it, a cylindrical (aneurysma cylindricum) or spindle-shaped (aneurysma fusiforme) or sacculated (aneurysma sacciforme) aneurism develops (Fig. 378). Of course, there are many transitions between each of these different forms.

A *B*

FIG. 382.—Arterio-venous aneurism of the left hand and forearm of a man forty-five years old, which had developed gradually after a bite on the hand received in his seventh year. Numerous sacculated aneurisms on the flexor side (*B*), and very marked varicose enlargement of the veins on the extensor side (*A*).

Occasionally an aneurism communicates with an adjoining vein, as was formerly not uncommon after phlebotomy, in consequence of simultaneous injury to the brachial artery at the elbow. An aneurism of this description Virchow calls an arterio-venous aneurism. This term is better than varicose aneurism or aneurismal varix. The arterio-venous aneurism takes the form either of a circumscribed, sacculated tumour, as illustrated in Figs. 379 and 380, or, as a result of the communication between the artery and vein, there occur marked disturbances in the circulation, with pulsating dilatations of the distant branches of both artery and vein (Figs. 381, 382). If pressure is applied to the point of communication between the artery and vein, the pulsation in the dilated and tortuous vessels ceases and they collapse. In the extremities the arterio-venous aneurism, as a

the communication between the artery and vein, leads to cir- disturbances throughout the entire limb, and to numerous eurisms and dilatations of the veins (varices), as in a case by Stromeyer and Krause (see Fig. 382).

rding to Bramann, of one hundred and fifty-nine cases of enous aneurism, one hundred and eight were due to an injury, following phlebotomy, twenty-nine gunshot wounds, five con- which caused no internal wound, and nine were spontaneous. four instances was an arterio-venous aneurism congenital. io-venous aneurism may develop spontaneously from a true , which becomes gradually adherent to the vein. The latter obliterated at the point of contact, or the aneurism ruptures open vein.

d or Racemose Aneurism.—In cirsoid or racemose aneurism . dilatation, tortuosity, and thickening of the artery throughout distribution, form- involuted mass of en- eries (Fig. 383). The aneurism occurs es- upon the scalp, is for part of congenital nd belongs more to tumours, and hence racemose angioma appropriate. Cirsoid is rarely acquired, in se it may result from chanical injury. A n used to be made be- soid aneurism (varix and the anastomotic (angioma arterial m, tumor vasculosus . The former was sult more from a dif- ation of the arterial and eventually of aries and veins; while

Fig. 383.—Cirsoid aneurism of the right and left angular and frontal arteries of a man twenty years old (Bruns). Ligation of the right external carotid and the left common carotid. Death from cerebral embolus.

was said to be made up of newly formed dilated and length- rial branches, resembling more closely a tumour. But both erge into one another to such an extent that it is impos- nake any distinction. An analogous tumour formation, the

so-called plexiform neuroma (see Tumours of Nerves), occurs in t nerves.

Dissecting Aneurism (aneurysma dissecans) is a particular kind traumatic aneurism resulting from rupture of the intima and me with preservation of the adventitia. It occurs especially in the ao and small cerebral arteries. The blood escapes between the media an adventitia and lifts one from the other.

Occurrence of Aneurisms.—As regards the occurrence of aneurisms, they are most common in the thoracic aorta (the ascending and transverse portions), appearing next in order of frequency in the popliteal, carotid, subclavian, innominate, axillary artery, etc. According to Lüttich, out of one hundred and ninety-six cases, one hundred and sixty-one were observed in men and only thirty-four in women. Aneurisms are comparatively common in England, particularly in the English army. The cirsoid aneurism is observed most frequently in the common iliac and on the scalp. Of aneurisms involving the small arteries, those in the brain, the lungs, and the heart are especially important. As regards the occurrence of aneurisms in bone the views of different authorities are divided. If they occur at all they are very rare. In the majority of cases of so-called bone aneurism we have to deal with a very vascular sarcoma, containing sometimes but very little sarcomatous tissue.

The Symptoms and Course of Aneurisms.—The most important symptoms of an aneurism are brought about by the blood flowing into the sac, and consist in the presence of pulsation and a friction sound. If a hand is placed upon the tumour it will be felt to enlarge synchronously with the apex beat. By palpation and auscultation the friction sound can also be made out; it is caused by the blood rubbing against the inner wall of the sac. As regards diagnosis, a careful distinction must be made between the actual, true pulsation of an aneurism and the communicated pulsation which results, for example, from a tumour or an abscess being lifted by an underlying large artery. If the pulsation is communicated, there is usually only a rise and fall in one direction, and the tumour does not expand equally in all directions, as is the case in the true pulsation of an aneurism. But the pulsation of aneurisms is not always plain, it being very slight, for example, in those with thick walls. If the afferent artery of an aneurism is compressed the pulsation and friction sound cease. Mention should be made of the fact, which is of diagnostic importance, that very vascular sarcomata of bone, for instance, also pulsate.

When an aneurism has once formed, the local dilatation of th lumen of the artery never returns to the normal again, but, on th

contrary, it constantly increases, and in addition the wall of the vessel becomes steadily thinner, and finally the sac bursts, leading to fatal hæmorrhage, especially in aneurisms of the aorta, the brain and lungs, etc. As a result of the increasing enlargement of the sac, the surrounding parts are proportionately displaced and the bones are gradually more or less eroded—for example, the sternum, the vertebræ, and ribs, in aneurisms of the aorta. Pressure upon adjoining nerves gives rise to corresponding symptoms (pain, paralysis). The skin resists comparatively the longest time, but it also may be broken through, causing sudden death from hæmorrhage.

Spontaneous cure of an aneurism by filling of the sac with a thrombus and by change of the latter into cicatricial tissue may occur in the case of smaller aneurisms and also in large sacculated ones. The thrombi originate from the slowing of the current and the pathological changes in the wall of the aneurism.

Extensive thrombi with many layers also develop in larger aneurisms, but in these cases complete obliteration of the aneurismal sac by cicatricial connective tissue does not take place. The thrombus formation sometimes increases to such an extent that the circulation is interrupted, and gangrene, possibly of the entire extremity, takes place. Occasionally the thrombi soften and break down, giving rise to embolic processes, or the thrombi may become calcified.

Diagnosis of Aneurisms.—From what has been said, it follows that the diagnosis of aneurism is not difficult as long as we have to deal with cases which are accessible to careful examination. As regards diagnosis, the above-described true pulsation and the friction sound, as well as their disappearance after compression of the afferent artery, are the most important symptoms. Nevertheless good surgeons have made errors and taken aneurisms for abscesses, particularly in cases where there are manifestations of inflammation, swelling of the soft parts around the aneurism, etc. If this mistake in diagnosis should occur, and the aneurism be incised, resulting in a gush of blood, the incision should be immediately closed by placing the hand upon it, the afferent artery compressed, Esmarch's rubber tourniquet applied, and the main afferent artery immediately ligated in its continuity.

On the other hand, it may happen that an aneurism is supposed to be present, while as a matter of fact we have to deal with a very vascular tumour. But from what has been said it should be an easy matter to make the correct diagnosis in such cases.

Prognosis of Aneurisms.—The prognosis of aneurisms varies greatly, according to their location. In general, the prognosis, as far as spontaneous cure is concerned, is unfavourable, as this termination is only possible in small arteries by the organisation of the thrombi, calcification, etc. In large aneurisms the sac constantly increases in size, and there is nothing to do but check the enlargement of the aneurism by proper local treatment, and possibly to extirpate it.

Treatment of Aneurisms.—Mention may be made first of the operative treatment of aneurisms. The oldest method of operative treatment is that of Antyllus. It consists in splitting open and extirpating the sac after previously performing central and peripheral ligation of the main trunk of the artery and any branches which may be given off from the aneurism. The aneurism is exposed with the aid of Esmarch's artificial ischæmia and opened by incision. After removing the clot from the sac a probe is passed into the afferent and efferent ends of the artery, and both are closed by a ligature. After this all branches given off at any point from the wall of the sac must be tied. The aneurism itself can then be extirpated, or, when this is too difficult, a portion of the sac may be left behind. The performance of this operation may present great difficulties, in the first place, on account of the numerous branches which spring from the wall of the sac, and then because the aneurism may so obscure the central and peripheral ends of the artery that it may be very difficult to find and ligate them. Other methods of operative treatment for aneurism consist in the ligation of the artery on the central or peripheral side of the aneurism. The central ligation of the afferent arterial trunk is either performed close above the aneurism (Anel), or at some distance from the latter at the so-called place of election, where the artery is easily accessible (Hunter). Ligation of the artery on the peripheral side of the aneurism has been recommended particularly by Brasdor, Wardrop, and Desault. The formation of a thrombus in the sac, and thus its diminution in size by the development of cicatricial tissue, are said to be favoured by all these methods. Their success is uncertain, and, particularly after ligation of the afferent artery, gangrene has been observed of varying extent in the region supplied by the artery. Ligation of the efferent artery is especially to be recommended when ligation of the afferent vessel is impossible or too difficult; thus, in aneurism of the innominate, for example, one would ligate the carotid and subclavian arteries. The best though at the same time the most difficult method is that of Antyllus. The next, as far as the certainty of its effect is concerned, is the ligation of the afferent arterial trunk close above the aneurism, while ligation of the efferent artery close below the aneurism is the most uncertain procedure. After ligation of the afferent artery at the place of election in Hunter's method, recurrence, as a general thing, easily takes place; nevertheless this method is of value for the reason that often in the neighbourhood of the aneurism the artery is the seat of atheromatous disease, which makes ligation impossible.

Of the other methods of treatment we should mention, in the first

place, digital and instrumental compression of the afferent artery, which is particularly adapted for aneurisms upon the extremities. This, also, is for the purpose of exciting a coagulation in the aneurismal sac. The procedure is entirely devoid of danger, but it is often so painful that the patient cannot endure it long enough. Sometimes even gangrene of the skin may occur at the point where the pressure is applied. The procedure must as a general thing be continued for several days, and it is best for the compression to be kept the same for several hours. The compression-treatment is adapted particularly to recent traumatic aneurisms, and less so to true aneurisms where there is atheromatous degeneration. It is less dangerous than the operative treatment. Erichsen found that in fifty per cent of the cases of ligation poor results followed, of which twenty-five per cent were due to gangrene. The least dangerous and the surest method of employing compression is digital compression, from which Barwell found only 6.8 per cent of deaths or amputations in consequence of gangrene. These good results are probably explainable by the fact that in digital compression the thrombus probably remains permeable for the blood-stream. There must be several persons who can relieve one another in performing digital compression. The main afferent artery is compressed at a point central to the aneurism for a variable length of time until the pulsation in the aneurism has stopped. In some cases the pulsation stops after two to three hours' compression, but at other times it has to be continued for several days—preferably with free intervals. Special pads, Esmarch's elastic bandage, or some simple substitute, such as a crutch or a broomstick, have been recommended for carrying out instrumental compression. Forced flexion of the extremity has also been used in place of instruments (see Fig. 96). Compression by means of elastic bandages can be employed as follows: The extremity is first enveloped by an elastic bandage from the periphery to the vicinity of the aneurism; an elastic bandage is then tied about the extremity just above the aneurism, and the bandage below removed; in about an hour and a half the upper bandage is removed. This elastic compression may then be followed by several hours of digital compression. Pearce Gould recommends the administration of dry albuminous food and large doses of iodide of potassium before using the elastic compression, in order to increase the coagulability of the blood.

The other methods of treating aneurism consist in exciting a coagulation of the blood in the aneurismal sac by chemical means—as by the injection of ergotin, liq. ferri sesquichlorat., alcohol, etc.—or by foreign bodies (catgut, silver, steel, or copper wire, horse-hair, lami-

naria), by acupuncture, by electropuncture and by the galvanic current (cathode on the aneurism). I consider any treatment by injection dangerous, and, consequently, not to be recommended; especially after the injection of liq. ferri sesquichlorat., extensive clotting and speedy death from pulmonary and cerebral emboli have taken place. As regards the results obtained by the introduction of steel or copper wire (filipuncture) into large aneurisms, as Moore does in the case of aortic aneurisms, the recently published statistics of Verneuil are very unfavourable. Of thirty-four cases treated in this way, only two were cured, and thirty died comparatively soon after the operation. Phillippe obtained satisfactory results in dogs by the introduction of silver or copper wire, horse-hair, laminaria, etc., into the femoral or carotid artery. I have obtained very remarkable results in aortic aneurisms by means of galvano-puncture, the technique of which is described on page 81, and also in the Regional Surgery.

The best treatment for cirsoid aneurism and for arterio-venous aneurism is extirpation, followed by careful arrest of all bleeding by ligation of the afferent and efferent vessels. In cirsoid aneurism ligation of the main afferent artery is also to be recommended; or igni-puncture may be performed with the galvano-cautery or with the fine point of the Paquelin instrument.

The treatment of ordinary aneurisms of course varies greatly with their location. In general it follows, from what has been said, that, whenever it is possible, compression should be tried first, alternating elastic bandaging with digital compression or compression by means of a stick. If this compression treatment is borne it can be continued for a long time. Not infrequently compression proves successful after the lapse of months. If compression cannot be carried out or is not successful, an operation, when possible, should be undertaken, the best being that of Antyllus, or, if the latter cannot be used, Anel's, Hunter's, or Brasdor's operation should be performed in the manner described above.

Varices or Varicose Veins.—By varix is understood a dilatation of the wall of a vein (Fig. 384). This originates for the most part from mechanical interference with the return flow through the veins, and, consequently, occurs in local or general stasis, such as that due to the presence of tumours, particularly in the abdomen, or to pregnancy; or it is due to cardiac disease, obstruction to the entrance of venous blood into the heart, etc. The greater the resistance, the greater will be the pressure under which the blood flows in the veins, and so much the sooner will the walls of the veins become stretched. Occasionally an inherited disposition towards varices must be acknowledged. In pre-

l individuals with flabby veins, comparatively slight causes may o excite varices. Thus varices are produced in the lower ies, for example, of individuals whose occupation compels them a great deal.

rrence of Varicose Veins.—As regards the occurrence of varices, particularly apt to be found in parts of the body where the ow of blood in the veins is rendered difficult, and consequently common in the lower extremities, at the anus hoids), in the scrotum, and in the spermatic ricocele). Women suffer from varices more ly than men, probably, in the main, as a result ancy. Their frequency also varies among rent races.

anatomical changes in varicose veins consist onic endophlebitis and periphlebitis with hy- y of the muscular coat at the beginning, the mild and in the advanced cases this coat ic.

toms of Varicose Veins.—The subcutaneous d also the deeper veins in the muscles are ilated, tortuous, and lengthened over an area le size. Blue, sacculated, tortuous bands and ions are seen, varying in size, ich the skin is usually more or ned. Not infrequently, as a re- upture of these varices and the g skin, secondary hæmorrhages ce which, in the lower extrem- nstance, may cause death if not y arrested; under these conditions a spontaneous arrest does y occur. Sometimes periphlebitic inflammation and suppura- inate in the parts surrounding the varices, possibly in conjunc- an eczema or ulcer in the skin. Thrombi are also observed s as a result of retardation of the blood current in the dilated just as in aneurismal sacs. They may or may not become d, soften and break down, or become calcified. If they become the so-called vein stones or phleboliths result. When thrombi e dilated veins are plainly to be felt as firm, hard cords. Sup- breaking down of the thrombi is observed, for example, in ion with an ulcer of the leg or eczema which has not been ntiseptically. In this condition there is danger of the develop- embolic processes and pyæmia from the carrying off of the

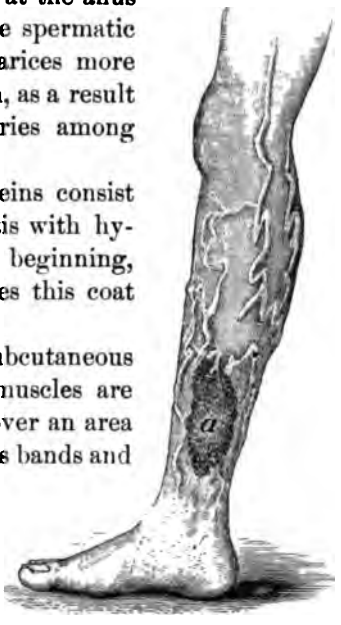


FIG. 384.—Varicose ulcer of the leg (*a*), resulting from varicose veins.

suppurating clots into the general circulation. It is a matter of great practical importance that wherever varices exist there is a tendency towards inflammatory processes, with increased transudation and cellular infiltration. Hence it is clear why the development of vesicles and eczemas which break down and ulcerate are so common upon lower extremities where there are varices. Should a small injury be received, there is, for the same reasons, only a slight tendency towards repair, and an ulcer may readily result. The ulcers of the leg, which are so common, are usually observed in conjunction with varicosities, and so are correctly designated varicose ulcers of the leg (Fig. 384). In such cases there usually exists a pronounced inflammatory condition in the lower extremity, with hyperplasia, extensive œdema, and, in severe cases, a deforming of the foot and leg by an induration resembling elephantiasis.

The diagnosis and prognosis of varices may be inferred from what has just been said.

Treatment of Varicose Veins.—The treatment of varicose veins varies with their cause and location. I must refer the reader to Regional Surgery for the detailed description of the treatment for varices of special localities—such as the leg, the rectum (hæmorrhoids), etc. Only the following brief statements can be given here: In the first place, varices can be cured by operative measures—such as extirpation after previously applying a catgut ligature, or by cauterisation with the galvano- or Paquelin cautery, as, for example, in the case of hæmorrhoids. In severe cases good results have been obtained from the removal of the varices, in the lower extremity, for example, by the following method: By allowing the leg to hang down from the operating table the varices are caused to become prominent; thin rubber tubing is tied around the upper third of the thigh, loosely enough not to compress the artery. The skin is divided by a longitudinal incision along the entire length of the varicose vein, and freed on both sides of the incision. The proximal portion of the vein—generally the saphenous—is secured by a double ligature, and the vein, with its ramifications, is removed from above downwards, without using the edge of the knife. The branches are seized by artery clamps and ligated. Percutaneous ligation (*Umstechung*) of the veins has also been recommended; a catgut ligature is carried on a curved needle under the vein and knotted on the skin, possibly over a drainage tube. Even after extirpation of the varices recurrences are rather common. In extensive varices involving, for example, the subclavian vein and its branches, I can recommend a very simple and effective method, namely, ignipuncture—i. e., puncturing the varicose venous trunks with the

galvano-cautery, or with the fine point of the Paquelin cautery. A protective dressing is ordinarily unnecessary, or, at the most, only for twenty-four hours. The puncture wounds dry and are covered by small scabs, which fall off after a time.

Ligation of the internal saphenous vein is perhaps the best treatment for the varices of the leg which are so common (Trendelenburg). Trendelenburg has practised this simple operation for years with the best results. Its success is very surprising. Varicose ulcers of the leg also heal with remarkable rapidity. Petersen recommends a circular incision about the leg through the skin and subcutaneous tissue; the veins are in part ligated and in part resected, and the skin sutured.

The bloodless methods of treatment are, for the most part, only palliative in their nature. In the varices of the leg, for example, they consist mainly in the use of dressings which exert pressure, particularly elastic stockings, or roller and elastic bandages. In general, Martin's cheap elastic bandage is preferable to the elastic stocking. If ulcers of the leg are present, they should be dusted with iodoform, dermatol, bismuth, or oxide of zinc, and over this dressing Martin's elastic bandage should be applied. With these bandages the patient can attend to his business. The bandages are taken off in the evening, thoroughly washed in water, and dried during the night. The greatest cleanliness is necessary in this method of treatment. Oftentimes the elastic bandage is not borne well, as it causes an eczema. In this case the rubber bandage should be left off and the eczema treated with diluted alcohol, some ointment, or dusted with starch, or starch and zinc oxide (5 to 10:1), over which a gauze and cotton dressing is placed. In varices of the lower extremity, Landerer recommends compression of the internal saphenous vein by a truss consisting of a spring made in the shape of a parabola, and a pad filled with water; this is worn above or below the knee.

Finally, mention should be made of the injection of drugs into the parts which surround the veins. Paul Vogt recommends cutaneous and subcutaneous injections of ergotin into the perivascular tissues. If this method is employed, as fresh solutions as possible of ergotin should be used (extract. secal. cornut., Wernich, 1 to 10 aq. destil.), to which it is a good plan to add a little carbolic acid (0.10) to prevent decomposition. It is wise not to permit the solution to stand for too long a time, but to renew it frequently. The solution is injected by a hypodermic syringe and the small punctured wound closed by iodoform collodion. If an abscess should result, it must be promptly incised. Injections of absolute alcohol, or of a few drops of concentrated carbolic acid, as in hæmorrhoids, are better than ergotin (Lange).

Care must always be taken to avoid any direct injury to the vein and to make the injections only into the perivascular tissues.

§ 96. **The Diseases of the Lymphatic System.**—The acute and chronic inflammations of the lymph vessels and glands have been sufficiently described under the subjects of inflammation (§§ 56 to 58), acute lymphangitis and lymphadenitis (§ 68), tuberculosis, scrofula, syphilis, etc. We shall return to tumours of the lymph glands in the chapters on New Growths.

There only remains to be briefly discussed here lymphangiectasiæ and lymph fistulæ with lymphorrhœa or lymphorrhagia.

Lymphangiectasiæ.—Dilatation of the lymphatic vessels (lymphangiectasis), from obstruction to the return flow of lymph, occurs under conditions similar to those which are present in dilatation of the veins. Lymphangiectasiæ are not infrequently observed as a result of recurrent attacks of hyperæmia and inflammations of various kinds. The hyperplasia of the skin and subcutaneous tissue occurring in conjunction with frequently repeated inflammations, and which is called elephantiasis, is in the main a true lymphangiectasis (see § 93). But, as a general thing, the return flow of lymph has so many channels through which it can pass that if stasis occurs compensation readily takes place, and for this reason an occlusion even of the thoracic duct may cause no serious trouble. Lymphangiectasiæ are observed most commonly in the lacteal vessels of the mesentery. In rare cases, as a result of some traumatism, there occasionally develop circumscribed subcutaneous or interstitial collections of lymph—so-called lymph extravasations or lymph cysts similar to the hæmatomata derived from the blood-vessels.

As regards the symptoms which lymphangiectasiæ give rise to, it should be briefly stated that in lymphangiectasiæ of the skin the latter is filled with dilated, tortuous lymph vessels; the skin for this reason has a nodular appearance; it is covered with vesicles, and frequently, as a result of hyperplasia of the tissues, comes to resemble elephantiasis. If the varices of the lymphatic network in the cutis are more pronounced, vesicles of different size develop. Not infrequently the varicose lymphatic vessels burst and give rise to a so-called lymph fistula. Gjeorgewic states that in fifty-five cases lymphorrhœa was observed twenty-two times in consequence of the spontaneous bursting of the varicose lymph vessels. The lymph usually exudes from one or more vesicles and sometimes from between the epithelial cells, as in one case which I saw, without an actual fistula being visible. Under these circumstances, the escape of lymph, the lymphorrhagia or lymphorrhœa may be very considerable. In one case of lymphangiectasis of the labia

majora in which a fistula developed, Nieden found that in four hours there was an escape of one and a half litre of a milky, slightly yellowish liquid containing fat and resembling chyle. The most serious lymphorrhagia is that which results from a rupture of the thoracic duct caused, for instance, by a traumatism or by an advanced degree of stasis, possibly from closure of its lumen by inflammation or a tumour in its neighbourhood. In such instances there is a great accumulation of lymph in the thoracic and abdominal cavities (chylous hydrothorax and chylous ascites), which will be described in the Regional Surgery.

In the rare cases of circumscribed, subcutaneous, and interstitial collections of lymph which, as a result of a traumatism, for example, has escaped from the vessels, there develops a fluctuating, circumscribed swelling which at the outset grows rapidly and then usually remains stationary (lymph cysts). Should the extravasation of lymph continue, a lymph fistula may eventually form from a rupture of the skin.

The microscopic changes in lymphangiectasiæ of the skin consist principally in the development of numerous irregularly shaped, complex cavities, lying in and close beneath the papillary layer of the cutis and, in fact, directly beneath the epidermis, which are lined with endothelium and communicate with the plexus of lymphatic vessels. Not infrequently lymphatic vessels with hypertrophic walls are found in the deepest layers of the cutis and subcutaneous cellular tissue.

Congenital Lymphangiectasis.—The lymphangiectasis is sometimes congenital, particularly in the tongue and lips (macroglossia, macrocheilia lymphangeiectatica), and also in the skin of the scrotum and labia pudendi.

Treatment of Lymphangiectasis, Extravasations of Lymph (Lymph Cysts) and Lymph Fistulæ.—The treatment of lymphangiectasiæ is in general the same as for varicose veins, and often enough it is unsuccessful. In many cases cauterisation with the fine point of the Paquelin or galvano-cautery renders excellent service. Successful extirpation may prove very difficult for the reason that the boundary between the diseased and healthy tissues is so hard to recognise. For lymph cysts compression should be tried, and if this fails, the sac should be laid open with or without cauterisation of its walls with a three- to five-per-cent. solution of carbolic acid. Lymph fistulæ have been cured by transverse division of the skin on the proximal side of the fistula. As regards the treatment of elephantiasis, injuries of the thoracic duct, and congenital lymphangiectasiæ, I must refer the reader to Regional Surgery.

§ 97. **The Diseases of the Peripheral Nerves.**—We shall confine ourselves here only to the surgical aspects of diseases of the nerves—i.e., we shall only take up those which are capable of surgical treatment. We have already, in a previous chapter, discussed the most important diseases of the peripheral nerves. Degeneration and regeneration of nerves, following contusion or division of them, has been described in §§ 87 and 88, where the sequelæ of injuries to nerves, the paralyses, and the vasomotor and trophic disturbances have been discussed. Trismus and tetanus have been described under the subject of Infectious Diseases of Wounds (§ 73), and the symptoms of shock in consequence of injury to the sensory nerves in § 63. Inflammation of the peripheral nerves (neuritis) has been described in connection with injuries of nerves (§ 87), but the subject must be briefly reviewed at this place.

Neuritis.—Neuritis occurs in an acute and chronic form. The most common causes of neuritis are injuries of various kinds, catching cold, inflammations of neighbouring organs, and acute or chronic constitutional diseases, such as typhoid fever, the acute exanthemata, diphtheria, syphilis, leprosy, chronic alcoholism, etc. All infectious processes are of the greatest importance in the etiology of diseases of the peripheral and central nervous system. Often enough no definite cause for the neuritis can be demonstrated.

Anatomically, acute neuritis is characterised by redness and swelling and generally by a serous, or sero-fibrinous or purulent exudation between the bundles of nerve fibres. Microscopically, in addition to the above-mentioned manifestations of hyperæmia and inflammatory exudation there is found a commencing degeneration of the medullary sheath and axis cylinder of the nerve fibres, and a proliferation of the nuclei in the sheath of Schwann. Occasionally the nerve perishes more or less completely from suppuration or gangrene. In chronic neuritis there is partly a new formation of connective tissue, an induration and sclerosis of the nerve, and partly a degeneration of the nerve substance. In a man who died of alcoholism Eichhorst found a peculiar degenerative atrophy of the peripheral nerve fibres without connective-tissue growth (neuritis fascians); there was also a corresponding atrophy of the muscles.

The symptoms of neuritis, as far as they concern the surgeon, have been described in § 87, under Injuries of Nerves. For further particulars we must refer the reader to the text-books on the pathology of nerves. We have remarked before that neuritis gradually extends in the form of an ascending and descending neuritis and gives rise to corresponding disturbances. The *treatment* of neuritis depends upon the

cause. In the main, the surgeon has to deal with injuries to nerves, of which the therapy has been given in § 88.

Multiple Neuritis.—Particular interest attaches to multiple neuritis, in the study of which Leyden has won great credit. He distinguishes the following forms: 1. The infectious form: paralyses following diphtheria, typhoid, and other infectious diseases, multiple neuritis in syphilis and tuberculosis. 2. The toxic form of multiple neuritis (lead, arsenic, and phosphorous paralysis, paralyses following CO and CS poisoning, ergotism, mercurial paralyses, alcoholic neuritis). 3. Spontaneous multiple neuritis following over-exertion, exposure to cold, etc. 4. The atrophic (dyscrasic, cachectic) form following anæmia (pernicious anæmia), chlorosis, marasmus, cancerous cachexia, diabetes, and tuberculosis. 5. The sensory neuritis, pseudo-tabes, neuro-tabes peripherica: *a*, the sensory form of multiple neurites; *b*, the sensory neuritis of tabes. The pathogenesis, course, and treatment will be found in the text-books on nervous diseases.

The relationship of the nervous system to diseases of the skin has been briefly stated in § 93, and we shall return to the subject of neuropathic bone and joint affections under Diseases of Joints. New growths of nerves are described under the subject of Tumours.

Traumatic Neurosis.—Traumatic neurosis or traumatic hysteria, which is caused by concussion of the brain and spinal cord from a fall, railroad accidents, severe contusions, etc., and sometimes by comparatively slight accidents, has already been described on page 285. The treatment of the traumatic neuroses is a subject that belongs to neurology.

Neuralgia.—By neuralgia (from *νεῦρον* and *ἄλγος*) is understood a disease of the sensory nerves the chief symptom of which is pain. The pain is usually localised in a particular nerve, is of considerable intensity, and is generally intermittent or remittent. The neuralgias belong to the most cominon neuroses, and their causes are very numerous. There often exists a pronounced neuropathic disposition. Of the most common causes there may be mentioned in particular traumatic and mechanical influences, inflammations, compression, disturbances of circulation, also taking cold, infections like syphilis, malaria, poisoning by lead or mercury, and finally diseases of the central nervous system, etc. Gussenbauer has directed attention to the fact that habitual constipation is a comparatively frequent cause of trigeminal neuralgia, and I can confirm his experiences throughout. The pain usually comes on in attacks of varying intensity and duration. The course of the neuralgia is sometimes acute—a few days or a week—and sometimes chronic, extending over weeks, months, or years. A large number of the cases are incurable, and last throughout the rest of life. Neuralgias of the trigeminus, the sciatic and intercostal nerves are particularly common.

Treatment of Neuralgia.—The treatment of neuralgia requires a of all that the cause of the disease should be determined by a careful examination of the patient. By overcoming habitual constipation, anæmia, affections of the genital apparatus, especially in women, etc., surprising cures of long-standing reflex neuralgias have often been brought about.

The forms of treatment of neuralgia itself are very numerous, and include particularly the use of electricity, narcotics (morphine, atropine), especially in the form of subcutaneous injections, and various drugs, such as chloroform, ether, nitrite of amyl, and chloral hydrate; also the internal administration of arsenic, quinine, preparations of iron, bromide of potassium, iodide of potassium, and strychnine. Among the newer drugs used for neuralgia are antipyrine, antifebrine, phenacetine, agathin (one half gramme for adults three times a day), and migranin (one and one-tenth gramme for adults three times a day). Surgical measures are often indicated, e. g., massage, nerve-stretching, neurotomy, neurectomy, extraction of the nerve, or neurolysis, i. e., liberation of a nerve that is compressed by a cicatrix, callus, etc. Electricity is sometimes very effective, especially the galvanic current. In addition to the above-mentioned remedies, counter-irritation of the skin, powerful electrical stimulation, vesicants, the red-hot iron, etc., may be tried. In suitable cases there is great advantage in sea-bathing or in hot springs (Gastein, Schlangenbad, Pfäffers, Ragatz, Wildbad, Wiesbaden, Teplitz, Leuk, etc.), or in cold-water cures, grape cures, and particularly in mountain life with proper exercise. Massage is often very successful.

Neurectomy and Extraction of the Nerves.—The surgical or operative treatment of neuralgia by neurectomy or extraction of the diseased nerves only succeeds when the neuralgia is dependent upon a peripheral cause. But even in such cases recurrences often occur, although no reunion of the divided nerve has followed the operation. After extraction of the affected nerve, the collateral branches which have been left intact may give rise to a recurrence, and permanent cures after neurectomy are rare, as is shown by the recent statistics of Conrad taken from the clinic at Bonn. Operations were performed ten to fifteen times for a facial neuralgia, for example, without a single permanent cure.

The technique of neurectomy and of extraction of the diseased nerves is described in the Regional Surgery.

Nerve-stretching.—Nerve-stretching was first practised by Billroth and Nussbaum for chronic affections of the nerves, for epileptiform attacks, and for neuralgias, and has been employed with greatly varying success for sciatica, tabes, and other nervous diseases. The oper

tion is performed by exposing and isolating the sciatic nerve, for instance, above the popliteal space or higher up at the lower border of the glutæus maximus, and having grasped the nerve with the thumb and index-finger, it is stretched by a vigorous pull until it has become plainly lengthened. Nerve-stretching is only indicated in diseases of the peripheral nerves and not in affections of the central nervous system. The effects of nerve-stretching are probably due to the production of an acute traumatic inflammation of the parts surrounding the exposed nerve, by which pathological conditions, such as degenerative processes, adhesions, etc., are improved. In cases of spasm of the facial nerve, and in severe cases of long-standing sciatica, I have practised nerve-stretching with good results.

Bloodless Stretching of the Sciatic.—For neuralgia of the sciatic nerve (sciatica) it is an excellent plan to employ bloodless stretching by extreme flexion of the straightened leg at the hip joint, combined with massage.

§ 98. **The Diseases of Muscles, Tendons, and Tendon Sheaths.**—Inflammation of muscles (myositis) originates most commonly from traumatisms, and secondarily from inflammation of the immediately adjoining parts as a result of disturbances of circulation, or in the course of infectious bacterial diseases (pyæmia, typhoid, glanders, etc.). The inflammatory process in the muscle is localised principally in the connective tissue lying between the primitive muscular fasciculi, in the perimysium internum, and causes secondary changes in the contractile muscular substance. In other cases the latter is primarily the seat, for instance, of atrophy and degeneration, and the changes in the intermuscular connective tissue are secondary.

Inflammatory Muscular Contracture.—Apart from the local inflammatory disturbances occurring in the various forms of myositis, contracture of the inflamed muscle is one of the most important manifestations. We shall discuss the subject of contractures more fully later on, and we shall see that they may originate from many causes, such as disease of the muscles, nerves, bones, and joints, or from cicatricial shrinkage. As regards inflammatory contractures, it may be briefly noted that every inflamed muscle loses its elasticity and extensibility to a greater or less extent, and that the patient instinctively avoids the pain due to the stretching of the muscle by shortening, or, in other words, contracting it. The inflammatory muscular contracture originates in this way, and may become very severe. In this class of inflammatory, purely myogenic contractures, belong also the so-called ischæmic muscular paralyses and muscular contractures, such as those which follow the too tight application of dressings, and which were

first accurately described by Volkmann, and then by Leser. The ischæmic contractures and paralyses are produced by cutting off the arterial supply, especially of the hand and forearm, for too long a time by tight dressings, Esmarch's constriction, ligation and injuries of the larger vessels, as well as by the prolonged action of excessive cold. The contractile muscular substance coagulates, undergoes waxy degeneration, and is subsequently absorbed (Heidelberg, Kraske). There is regularly found a noticeable diminution or absence of muscular nuclei (Molitor), and the nuclei of the smallest capillaries also share in these changes. In such cases the muscle is no longer capable of regeneration; it dies. It is really a *rigor mortis* of the muscle, though the nerves retain their power of conduction. If the ischæmia does not last so long a time, only a part of the muscular fibres undergo degeneration, and the rest persist and retain their power of regeneration. The ischæmic contracture is marked by a high grade of resistance to extension into a straight position. The prognosis of the ischæmic paralysis and contracture depends upon the number of muscular fibres which have perished, the worst cases being incurable, and even the milder ones requiring vigorous treatment by massage, electricity, and passive motion. An attempt should always be made to stretch the shortened and stiffened muscles, if necessary, under chloroform narcosis.

Myositis Serosa and Sero-fibrinosa.—The slight degrees of inflammation of muscle—the *myositis serosa* and *sero-fibrinosa*—which may follow contusions, for example, are characterised anatomically by a saturation of the perimysium with serum and by cellular infiltration, particularly between the muscle fibres. The latter remain intact, or, according to the nature of the excitant of the inflammation, they undergo a cloudy swelling, fatty degeneration, and coagulation necrosis. The defect in the contractile muscular fibres is more or less restored by proliferation of the muscular corpuscles (see page 483, Regeneration of Muscle). If a severer grade of inflammation, such as a *purulent* myositis, occurs, the muscular fibres are destroyed *en masse* by degenerative processes; they break down and undergo suppuration and putrefaction. Myositis purulenta may be acute or chronic, taking the form of muscular abscesses or of a diffuse suppuration or putrefaction, as described in the chapter on Cellulitis. The suppurative and gangrenous inflammations of muscle are always due to bacterial infection, and are observed in conjunction with infected, septic wounds of various kinds, occurring in the course of pyæmia, erysipelas, typhoid, glanders, endocarditis, etc. Multiple abscesses in different muscles often occur in great numbers. The muscular abscess occurring in the course of tuberculosis, the so-called cold abscess, such as the tuber-

cular abscess or suppuration of the psoas muscle following tubercular disease of the vertebræ, runs an exceedingly chronic course unless it receives energetic surgical treatment. Diffuse suppurative and gangrenous changes in muscle are particularly apt to make their appearance in conjunction with a compound fracture which has not been treated aseptically.

Wherever muscular tissue has been destroyed by suppuration or gangrene there will remain, after healing has taken place, a permanent defect which is repaired by connective tissue, since, as we remarked on page 483, contractile muscular substance possesses but slight powers of repair. Corresponding to the size of the defect, the connective-tissue adhesions and the increasing cicatricial contraction, disturbances in the functions of the muscles will subsequently develop in the form of contractures, which may render the affected extremity completely useless.

Myositis Fibrosa.—Chronic inflammations of muscle sometimes take the form of a *myositis fibrosa.* In this we have to deal, in the main, with a growth of firm connective tissue between the muscular fasciculi and a proportionate atrophy of the latter. This fibrous myositis, or sclerosis of a muscle, occurs either diffusely, changing the entire muscle into tough connective-tissue masses, or it is confined to certain spots. In this category belong the myositis fibrosa of the biceps or sterno-mastoid muscles, for example, occurring in the course of syphilis, or after paralyses, or primary muscular atrophies due to different causes, and also the so-called rheumatic indurations. In the latter the inflammatory process—i. e., the interstitial myositis—begins in the lymph vessels and small veins and leads to the production of a vascular connective tissue and to secondary atrophy of the muscle-fibres. The inflammation is probably due to micro-organisms. The treatment of these indurations consists in warm local baths, massage, inunctions of unguentum cinereum, and possibly in excision (Strauss). Indurations of muscle may also result from the invasion and encapsulation of trichinæ (Curschmann).

Myositis Ossificans.—Special interest attaches to *myositis ossificans.* The development of bone in muscle is observed under various pathological conditions; for example, in conjunction with callus formation after a fracture. Bone occasionally forms in muscle as a result of some frequently repeated traumatism, such as the kick of a gun, which may give rise to the development of bone in the biceps and pectoralis muscles (the so-called exercise bones). Riding may lead to bony formation in the adductors of the thigh (riders' bone). Two kinds of myositis ossificans can be distinguished. In one form the new forma-

tion of bone starts in the periosteum and involves the muscle secondarily, and in the other variety it begins in the muscle, and the new bone either remains independent of the periosteum or becomes connected later with the periosteum and bones. The affection is probably of traumatic origin, particularly the first form; a single trauma or repeated traumatic influence gives rise to an ossifying periostitis which spreads to the muscle secondarily, particularly at its point of insertion on the bone. It is really an exostosis formation which spreads to the muscle as in the very interesting case described by Lange (see page 607, Fig. 403). In rare cases free osteomata are found which are not con-

FIG. 385.—Ossified M. brachialis internus; the tendon is not ossified (Blasius and Volkmann).

FIG. 386.—Myositis ossificans multiplex progressiva of the muscles of the back in a man twenty-four years old (Helfreich).

nected with the bone. In those instances the osteoma formation may be caused by a local congenital anomaly of development as assumed in the case of myositis ossificans multiplex progressiva (see below). It is also possible that here too traumatism may be of etiological importance. One can imagine that in consequence of an injury periosteum or small fragments of bone may become lodged in the neighbouring connective-tissue or muscle, or that osteoblasts may be carried by the circulation from some point of injury of the periosteum or bone to the muscle, and in this way give rise to the formation of an osteoma. Fig. 385 represents a case in which the brachialis anticus was completely changed into bone. Düms observed, in connection with the formation of bone in the deltoid muscle, a reflex neurosis, consisting of tremor and pains

ı the entire arm down to the finger tips, which only occurred when he gun pressed upon the exercise bone (osteoma), and disappeared ompletely after its extirpation.

Myositis Ossificans Multiplex Progressiva.—This is a very peculiar affection which sometimes begins during childhood. A great number of muscles gradually change into bone, causing the condition of the patient to become extremely deplorable. The disease runs a very chronic course, lasts for years, and is often characterised by typical attacks of fever and pains with subsequent bone-formation. After the reception of some slight traumatism, or without any apparent reason, painful doughy swellings develop in the muscles and intermuscular connective tissue, and in a few days they disappear. A preliminary stage of fibrous induration can usually be made out (Lexer). Inflammatory fibrous proliferation of the perimysium internum and degeneration of the muscular fibres result in the formation of fibrous nodules primarily in the muscle and independent of the bone. True bone is then gradually formed, partly from the bone itself in the vicinity of the muscular insertions and partly in the muscle. Nodular, branching masses of bone develop, especially in the muscles of the back and neck (Fig. 386). The jaws may be firmly held together by ossification of the masseters, and the movements of the vertebræ and the different joints may become lost in consequence of the ossification of the muscles, tendons, and ligaments. These pitiable individuals finally die in misery from motor disturbances, or from interference with respiration and nutrition.

The nature of this very remarkable disease is still but little understood. There is evidently a pronounced tendency to the formation of bone in the connective tissue of the muscles, fascia, tendons, and ligaments, as though periosteum had strayed into these tissues. The affection is, in all probability, a congenital anomaly of development, especially as in some cases malformations of the extremities have been present at the same time (micro-dactylism, congenital anchylosis of the joints of the big toes and of the thumbs) Stempel regards the process as an imperfect differentiation of the original embryonic gelatinous tissue representing the mesenchyma from which on the one side connective tissue and on the other cartilage and bone-tissue develop. If this normal differentiation is disturbed cartilage and bone develop in places which should be filled only with connective tissue. Pincus has advanced the theory that the disease is in the main traumatic in nature, and is probably caused by lesions of the soft parts at the time of delivery. It is perhaps possible that the new formation of bone is caused by osteoblasts which are carried through the circulation. The chief question is: Where does the bone originate? In the intermuscular connective tissue, in the muscle, or from periosteum and bone, and then invade the muscle secondarily? Both ways are possible. I believe with Virchow that in most cases the new

bone formation starts in the periosteum or bone and then extends to the muscles secondarily; in other words, that there is a multiple exostosis formation with secondary ossification of the muscle and connective tissue. Besides this there are cases where new bone develops primarily in the intermuscular connective tissue and the muscle itself and is not connected with the bone, so that the bony tumour can be grasped with the hand and moved freely. In the latter case this ossification takes place according to the endochondral as well as the periosteal type. In a typical case which Stempel observed for three years and a half the formation of bone started in the connective tissue. In a similar case of Roth's almost all the bony growths were connected with the bone itself. I think the disease should be looked upon not as an inflammatory process, but as a tumour formation—i. e., either multiple exostoses or multiple intramuscular osteomata in the connective tissue.

The treatment of the severe cases of myositis ossificans offers no hope, but the milder cases may derive some benefit from iodide of potassium and inunctions of ungt. hydrarg. ciner. Whenever possible, operative measures should be undertaken—i. e., the ossified muscle should be extirpated, and, if it be connected with the periosteum and bone, the periosteum and cortical layer of bone should also be removed.

The treatment of the above-mentioned acute and chronic inflammations of muscle is conducted upon the lines which have been laid down for the treatment of inflammation and suppuration.

Calcification of the Muscles has no clinical importance. It occurs in the neighbourhood of inspissated abscesses and in indurated inflammatory swellings. Extensive calcification, such as Meyer observed in the muscles of the leg, is exceedingly rare.

Muscular Rheumatism.—Acute and chronic muscular rheumatism depend upon inflammatory changes which are, to be sure, slight in amount. There are usually no gross anatomical changes in a chronic muscular rheumatism which has lasted for years; but the acute form is, for the most part, a serous or sero-fibrinous myositis. We still know but very little about the nature of muscular rheumatism. The manifestations of acute muscular rheumatism are very much like those exhibited after subjecting the muscles to some traumatism. The chief symptom consists in the more or less severe pains in the muscle. It occurs especially as lumbago and as rheumatism of the sterno-mastoid muscle (rheumatic torticollis). In addition to the rheumatic forms of lumbago there is also a traumatic form which follows, for example, forced forward flexion of the back. The rheumatic affection of the sterno-mastoid is usually accompanied by a marked contraction of the muscle, causing the head to be inclined toward the affected side.

Chronic muscular rheumatism is characterised by shooting, tearing, generally vague pains in the substance of the muscle, which are usually

excited or increased by bad weather. In the subsequent course of a given muscular rheumatism it often turns out that some constitutional disease is present, such as syphilis, tuberculosis, carcinoma, etc. I share Erben's opinion that true muscular rheumatism is rare, and that it is often made to include other diseases, such as neuralgia, inflammations of neighbouring joints—e. g., of the spine in cases designated as lumbago. In every case one should determine where the pain on pressure exists, whether in the muscles, nerves, bone, or joints, and the treatment should be directed toward the diseased condition that is found. The best treatment for the true acute and chronic muscular rheumatism consists, according to my experience, in the use of massage, in the diligent exercise of the affected muscles, and also in cold-water cures and the use of warm springs (Teplitz, Wiesbaden, Rehme, Gastein, etc.). Electricity is also serviceable; but massage, skilfully administered and combined with muscular exercise, is the best therapeutic measure.

Tuberculosis of Muscles.—Tuberculosis of the muscles is most commonly secondary to tubercular disease of the surrounding parts, or it follows deposition of the tubercle bacilli by the circulation, such as occurs in general miliary tuberculosis (see § 83, Tuberculosis).

Syphilis of Muscles.—Syphilis may become localised in muscles, occurring sometimes in a diffuse form, as myositis fibrosa, and sometimes circumscribed, as a gumma tumour, especially in the sternomastoid muscle. Braman is right in calling attention to the fact that many of the so-called rheumatic indurations of muscle are due to syphilis.

Muscular Atrophy.—*Atrophy* of the muscles is observed in various pathological conditions. Atrophy and degeneration may follow inactivity of the muscles (atrophy of disuse), such as, for example, occurs temporarily after the application of immobilising dressings for fractures or joint disease; or it may be due to disease of the central or peripheral nervous system (neuropathic atrophies), or to the above-mentioned inflammatory processes, traumatisms, etc. The muscular atrophy accompanying joint affections is sometimes not the result of disuse, but is caused by the local disease near by—that is, by an involvement of the muscles in the diseased process going on in the joint, as is the case particularly in acute articular rheumatism (Strümpell). According to Paget, Hoffa, and others, the muscular atrophy accompanying joint disease is essentially reflex in its nature—i. e., the terminations of the nerves in the joints are irritated by the inflammation going on there. This irritation is carried centripetally to the ganglion cells in the anterior horns of the grey matter in the spinal cord—i. e.,

to the spinal centres of the nerves governing the nutrition of the atrophying muscles—and excites in them certain changes which produce the muscular atrophy. The reflex atrophy does not take place in dogs, for example, when the knee-joint is inflamed, if the posterior roots of the third, fourth, and fifth lumbar and first sacral nerves have been divided (Hoffa, and others). I share the opinion with Sulzer, Strasser, and others, that the muscular atrophy in joint diseases is mainly an atrophy of disuse, and one can often demonstrate that the amount of atrophy depends upon the degree of mobility of the joint. Besides this atrophy of disuse the trophoneurotic reflex atrophy due to the joint lesion also comes into consideration, particularly in the wholly unused muscles.

Anatomically, we distinguish the following forms of muscular atrophy:

1, Simple atrophy of the muscular fibres; 2, atrophy, with an interstitial growth of fat cells (lipomatosis of the muscles); and, 3, degenerative atrophy.

Simple Atrophy.—In simple muscular atrophy following local or constitutional disturbances of nutrition, the muscular fibres decrease in size and number, and no other anatomical changes can be found. Atrophy of the muscular fibres, with a growth of adipose and connective tissue between the muscular fibres, is frequently observed. Generally the growth of the fat and connective-tissue cells is secondary to primary atrophy and degeneration of the muscles. Occasionally the development of fatty tissue in the muscle is so extensive that the latter increases in size. This is the case in the following form:

Pseudo-hypertrophic Muscular Paralysis (Erb).—This disease occurs almost exclusively in children, particularly boys, and consists in a gradually developing simple atrophy of the muscles, with a secondary interstitial growth of fat cells (Fig. 387), which may become so pronounced that many muscles—among others those of the calf of the leg—become considerably increased in size. In addition to these abnormally hypertrophied muscles there are others which are greatly emaciated. The atrophy spreads, and involves the greater part of the muscular system; the paralysis of the muscles steadily increases, and the patients become constantly more helpless. Death usually occurs within five to ten to fifteen years from marasmus or from paralysis of the muscles of respiration. The pseudo-hypertrophy is a primary disease of the muscles, and is probably due to a congenital change in the muscular tissue, which, at the period when development takes place, leads to a growth of fat in the perimysium internum and to atrophy of the muscular fibres.

Fatty Degeneration.—The fatty degeneration of the muscular fibres belongs to the degenerative atrophies of muscle. In this the primitive muscular fasciculi change into fat as a result of inflammatory processes, or inactivity due to paralysis, or of trophic disturbances due to a degeneration of the anterior roots of the spinal nerves; or it may occur in connection with an anchylosis or one of the acute infectious diseases (typhoid fever, diphthe-

ia), or may follow phosphorus poisoning, etc. The so-called progressive muscular atrophy belongs to this group. The form of progressive muscular atrophy described by Duchenne and Aran is produced by spinal disturbances, while other forms are dependent upon multiple disease of nerves, or have the nature of primary muscular affections. To this latter class of cases belongs juvenile muscular atrophy (Erb), which runs its course sometimes with, and sometimes without, lipomatosis. The atrophy of the muscles is, for the most part, primary, and as it increases paralysis gradually develops. The disease begins in a particular group of muscles, often, for example, in the

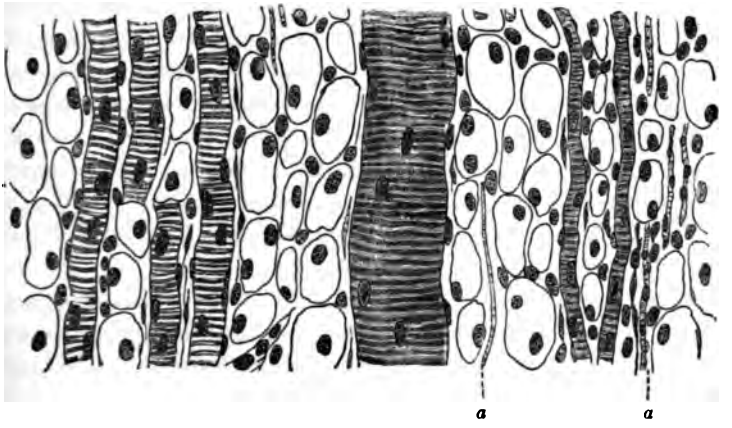


Fig. 387.—Lipomatosis (pseudo-hypertrophy) of the muscles. Development of fat between the muscle fibres; at *a* remnants of broken-down muscle fibres. × 200.

hand or the ball of the thumb. The atrophy then spreads intermittently, and in the severest cases gradually attacks the majority of the muscles. Progressive muscular atrophy belongs to the domain of nervous diseases, and consequently we cannot take it up more fully here.

Waxy Degeneration occurs especially in typhoid and puerperal fevers, as a result of contusions, in tetanus, and after the muscles have become thoroughly tired out by electrical stimulation (Roth). We have to deal in this condition with a death of the contractile muscular substance and its coagulation into a translucent hyaline mass.

Amyloid Degeneration of the Muscles.—Amyloid degeneration, which may involve the muscles of the tongue and larynx as a result of inflammatory processes, is a very rare disease of muscle. According to Ziegler, amyloid degeneration affects the perimysium internum and sarcolemma, causing them to become thickened and present a homogeneous appearance, while the contractile substance disappears.

Hypertrophy.—*Muscular hypertrophy* has no practical interest; it is partly acquired and partly congenital.

Muscular Defects.—Congenital muscular defects, which may occur in the pectoralis major and minor and in other muscles, should also be mentioned.

Tumours of muscles are discussed under the subject of tumours. Of animal parasites which occur in muscles there are the trichina, the *Cysti-*

cercus cellulosæ, and the echinococcus (see Regional Surgery). Marguet states that the echinococcus is found most frequently in the adductors of the thigh, in the glutæi, the quadratus femoris, biceps of the arm, the pectorales, the trapezius, deltoid, and muscles of the back and abdomen. They form fluctuating tumours which should be removed by extirpation or by incision followed by scraping them out. Actinomycosis of muscles is described in § 86.

Inflammations of the Tendons and Tendon Sheaths may occur, in the first place, as an acute dry tenosynovitis (tenalgia crepitans), a form which corresponds to dry pleurisy (pleuritis sicca). This is characterised by a deposition of fibrin upon the inner surface of the tendon sheath and upon the surface of the tendon. As a result of this roughening, when the tendon is moved a soft crepitation or a grazing or creaking sound is communicated to the hand held over the inflamed region. This form of tenosynovitis affects most commonly the extensor tendons of the forearm in individuals who work at heavy manual labour; it may also occur in the tendons of the leg (the tibiales and Achilles tendons) after a long march, for example.

The treatment of tenalgia crepitans consists in painting the parts with tincture of iodine, in immobilising them with proper dressings (splints, etc.) and applying moderate pressure with cotton, and later employing massage and passive motion. I use massage as soon as possible. Recovery usually takes place in one to two to three weeks.

Acute Suppurative Tenosynovitis.—Suppurative inflammation of the tendons and tendon sheaths (tenosynovitis acuta purulenta) is most commonly the result of some injury which has not been treated antiseptically, or of a suppurative process in the neighbourhood. Suppurative inflammation of the tendons and tendon sheaths has been described under the subject of Cellulitis, in § 70, and consequently will be only briefly mentioned here. In the fingers, especially, the so-called paronychia or felon easily spreads to the tendon sheaths (panaritium tendinosum). Suppurative tenosynovitis is characterised by a collection of pus between the tendon and its sheath, and by a cellular infiltration of the intrafascicular connective tissue. The milder cases, which are treated by incision and antiseptic dressings, terminate in a *restitutio ad integrum*; in others, an adhesion of the tendon to the tendon sheath or death of the tendon take place.

The *treatment* of suppurative tenosynovitis consists in making an incision at the earliest possible moment, followed by drainage and antiseptic dressings. It is a very important matter to place the diseased limb in a suitably elevated position. If the hand, for example, is involved, it should be suspended vertically by means of suspension splints (see Fig. 194). If the suppuration of the tendon sheaths is

extensive, the same treatment should be employed as was described for cellulitis in § 70. The poultices which used to be employed have been given up entirely, and the ice treatment is also not very effective. Whenever it is possible, suppuration should always be anticipated, and its extension should be prevented. If necrosis of the tendon occurs, care should be taken to keep the affected portion of the limb in the position in which it will be the most useful afterwards. The treatment of defects in tendons is discussed on page 482.

Tuberculosis of the Tendon Sheaths.—Tubercular tenosynovitis occurs both as a primary disease and secondary to tuberculosis in the neighbourhood. Primary tuberculosis of the tendon sheaths is not so rare as used to be believed; it develops occasionally from some traumatism (contusion, sprain). Tubercular tenosynovitis is characterised by the formation of miliary tubercles, greyish-red, gelatinous granulation tissue, and in the later stages by the formation of caseous or suppurating masses which are distributed along the tendon. In the benign cases of tuberculosis of the tendon sheaths, Goldmann states that the process is a fibrinoid degeneration, and that cheesy degeneration does not occur. The fibrinoid degeneration often leads to the formation of rice bodies—that is, the degenerated fibrous and villous growths break loose and become free corpuscles (corpuscula oryzoidea), which are like grains of rice; in this way the so-called rice-body hygroma develops (see page 559). König, on the other hand, claims that all rice bodies in tubercular joints, tendon sheaths, and bursæ are formed from fibrin; some result from clots of fibrin which are formed in the synovial fluid, and others from deposits on the wall of the synovial cavity which have become partly organised by the cells of the latter. In my opinion the rice bodies are formed in both ways, but in the great majority of cases they are the result of a degenerative process, as described by Goldmann, and the formation of fibrin is usually secondary. Rice bodies are also formed in the same way in non-tubercular joints, bursæ, and tendon sheaths (see also page 581).

The *treatment* of tubercular tenosynovitis consists in carefully removing the tubercular deposit with the scissors, forceps, and sharp spoon. I have obtained excellent results, and even entire cures, in primary tuberculosis of tendon sheaths. Care must always be taken that every bit of the diseased tissue is removed. Iodoform injections which are very efficacious are discussed on page 429. Losses of substance in tendons can be remedied as described on page 482.

Hydrops Tenovaginalis (*Hygroma of the Tendon Sheaths*).—By hygroma or hydrops tenovaginalis is understood a cystic formation which occurs especially in the tendon sheaths of the hand, particularly in the

palm, where it affects the flexor tendons beneath the anterior annular ligament, also in the fingers and on the dorsum of the hand. It consists essentially of an abnormal increase in the secretion of the tendon sheath. Some hygromata are, as we have said, tubercular in their origin. To avoid repetition, we shall discuss hygroma of the tendon sheath, together with hygroma of bursæ, in § 99.

Tumours of Tendon Sheaths.—We shall return to tumours of the tendon sheaths under the subject of tumours. Fibromata, fibrosarcomata, sarcomata and lipomata are liable to occur in this situation. The latter kind of tumour occasionally forms diffuse growths (lipoma arborescens) which are sometimes symmetrical.

Rice Bodies in Tendon Sheaths.—I have already described the formation of rice bodies in tuberculosis of tendon sheaths. Similar fibrous or cartilaginous formations are sometimes observed in syphilis, gout, after injuries, and occasionally without a demonstrable cause. These bodies sometimes reach a considerable size, and then resemble floating cartilages.

Myotomy and Tenotomy.—Brief mention should here be made of the subcutaneous division of muscles and tendons—subcutaneous myotomy and tenotomy—an operation which is often practised for contractures. The operation is performed in the following manner: The tenotome, a pointed, slightly curved knife (see Fig. 57, page 71), is introduced with antiseptic precautions, and the muscle or tendon—it may be the tendo Achillis or contracted fascia—is cut through subcutaneously. The small punctured wound is covered with an antiseptic dressing which exerts pressure. The gap which forms between the retracted ends of the tendon is then filled in by newly developed connective tissue. The missing portion of tendon becomes entirely regenerated, and the muscle suffers no loss of function. The intervening portion of tendon is developed from the cellular sheath, that wide-meshed connective tissue which partly envelops the tendon and is partly inserted upon it by means of bands (vincula tendinum). The technique and indications for myotomy and tenotomy in particular portions of the body are discussed in the Regional Surgery.

§ 99. **The Diseases of the Bursæ.**—The bursæ mucosæ are more or less sharply defined connective-tissue sacs having a smooth inner surface which is covered with endothelium, and, like the joints, secrete synovia.

Origin and Occurrence of Bursæ.—Bursæ, as a rule, develop in place where the skin, fascia, muscles, etc., are subjected to continual pressure and friction, particularly over bony prominences. This explains why the number of bursæ is not constant, and why bursæ form in portions of the bo

other than where they normally occur (so-called accidental or supernumerary bursæ). One may thus develop upon the first metatarsal bone in hallux valgus, over the spinous processes in kyphosis of the vertebræ, upon the sternum of shoemakers, etc. Young children lack a large number of bursæ which subsequently develop as the parts become subjected to increased use. Bursæ originate from the soft connective tissue which lies between two layers of tissue, and which becomes more and more wide-meshed. The space in the tissues is at the outset irregular and contains atrophied connective-tissue fibres, but it develops by degrees into a complete sac with smooth walls and endothelium like any other connective-tissue space. The number of the more or less constant bursæ is very great. Gruber found eighteen in the parts around the knee joint and eleven bursæ musculares at the elbow joint, in addition to the bursa anconea epitrochlearis and epicondylica. Velpeau found fourteen bursæ on the dorsum of the hand, etc.

Acute Inflammation of a Bursa.—The acute inflammation of a bursa (acute hygroma, bursitis acuta) is either serous, sero-fibrinous, or purulent. All cases of acute bursitis give rise, in consequence of the increased secretion, to a more or less prominent fluctuating tumour. The purulent inflammation occasionally takes on a phlegmonous character, causing the pus to burrow into the neighbouring cellular tissue or into joints, etc. The bursa most commonly inflamed is the bursa præpatellaris (see Regional Surgery).

Chronic Inflammation of Bursæ (Hygroma).—The most common form of the *chronic* inflammation of bursæ is the hydrops or hygroma. In the majority of instances it occurs as a painless fluctuating tumour, without change in the cutaneous covering. Its contents consist of a thick, mucoid liquid. The shape of the tumour corresponds to the degree of extension of the bursa. The hygroma præpatellare is the most common of all hygromata of bursæ (see Regional Surgery). Should a communication exist between the hygroma and a joint, a corresponding serous effusion will be found in the latter. Hygromata sometimes develop in connective tissue from fibrinous exudation without the previous formation of a bursa.

In other cases of hygroma the walls become thickened to a greater or less extent (fibrous degeneration), particularly if the disease has existed a long time, or a villous growth takes place in the bursa and the villi may break loose and form rice bodies (corpuscula oryzoidea). Occasionally there will be so many free bodies in the hygroma that the latter feels like a bag filled with shot (ganglion crepitans, hygroma proliferum). As already mentioned on page 579, these rice bodies in tubercular and non-tubercular tendon sheaths, bursæ, and joints result in the main from degeneration of tissue. Free bodies may also be formed by growths of cartilage which break loose from the hygroma.

The shape of the body is round, elongated, faceted, or like a pear, cucumber, or melon. Their number varies greatly, often reaching many hundreds.

The hygroma of the tendon sheaths mentioned on page 579 presents practically the same manifestations as that of the bursæ.

A hygroma originates almost always from mechanical causes, especially from prolonged mechanical irritation, from contusions, sprains, etc. Volkmann believes that the rare cases of multiple hygromata are occasionally due to rheumatic causes. Syphilis and particularly tuberculosis also give rise to the formation of hygromata, which in some cases contain rice bodies.

Part of the proliferating hygromata must be looked upon as tumours, some of them being benign, endothelial growths (Morisani), and others malignant, sarcomatous tumours (Mikulicz).

The best treatment of hygromata consists in puncture followed by antiseptic irrigation with a 1-to-1,000 solution of bichloride of mercury or a three-per-cent. solution of carbolic acid; or, better still, an incision should be made and the hygroma extirpated with antiseptic precautions as completely as possible. The procedures which were practised in the days before antisepsis (application of the tincture of iodine, pressure, etc.) are not sufficient (see Regional Surgery).

The treatment of acute inflammation of bursæ is conducted according to general rules. Painting the part with iodine, pressure, and massage will often suffice for the milder serous effusions. If there is a violent inflammation or suppuration, aseptic incision is the only proper procedure. In the case of large, purely serous effusions, puncture, with or without antiseptic irrigation, with a 1-to-1,000 solution of bichloride or a three-per-cent. solution of carbolic is usually sufficient.

Hæmatomata of the Bursæ.—The effusion into the bursa is bloody, when, as a result of some injury, there has occurred an extravasation of blood into the bursa, or when traumatic or inflammatory hæmorrhages have taken place from the wall of the hygroma. The treatment of these hæmatomata of bursæ is essentially the same as that for pure hygromata.

Ganglion.—The so-called ganglion generally takes the form of a round, elastic tumour, lying beneath the skin and occurring in the neighbourhood of joints, particularly those of the hand and foot. Many authorities have classed it with the hygromata of bursæ and tendon sheaths, but Volkmann is right in distinguishing the ganglion from these. He states that the ganglia have a genetic connection with the joint cavities, less often with the tendon sheaths, and are to be regarded as new growths in a limited sense of the word. The ganglion origi-

nates from a pouch-like appendage of the joint or diverticulum of the synovial membrane. The diverticulum becomes filled with thickened synovia, and may be completely cut off from the joint by obliteration of its pedicle; it practically becomes an independent cystic tumour. Ganglia are to be regarded essentially as synovial herniæ. Less frequently they originate from a kind of cystic degeneration of the capsule, or in other wounds from an abnormality in the secretion of the synovia. There are, it is true, intermediate forms between ganglia and hygromata.

The treatment of ganglia consists in bursting them subcutaneously by pressure with the finger, or by the blow of a wooden hammer, e. g., upon a seal which is enveloped in cloth and placed upon the ganglion, or in puncturing or incising the tumour subcutaneously with a tenotome and then applying a dressing which exerts pressure. Recurrences are very common after these methods of treatment. Jordan recommends the injection of iodine and glycerine (iodine 0.7, potassium iodide 2.0, glycerine 30.0) followed by massage and a compressive dressing after the contents of the ganglion have been previously removed by aspiration. Out of twenty-five cases treated in this way twenty-four showed no recurrence after one and three-quarter years. The surest and safest procedure is free aseptic incision, followed by as complete an extirpation of the ganglion as possible. This operative treatment is entirely devoid of danger if the rules of antisepsis are carefully observed. (See also Regional Surgery for the treatment of ganglion at the wrist.)

§ 100. **Gangrene (Necrosis) of the Soft Parts.**—When treating of the subjects of inflammation and injuries, we showed that they often caused death of tissue, mortification, necrosis, or gangrene. It may be well to give at this point a concise description of gangrene of the soft parts following inflammation and injuries.

Gangrene is to be regarded as a disturbance of nutrition arising from local vascular changes, diseases of the nerves, constitutional conditions (syphilis, alcoholism, diabetes, etc.), from injuries to vessels or nerves, burns, freezing, in the course of general (bacterial) infectious diseases (pyæmia, septicæmia, typhoid fever, etc.), or from severe local inflammations, such as cellulitis, etc.

Causes of Gangrene.—The causes of tissue death are as follows: 1. Interruption of the afferent flow of arterial blood without the development of a collateral circulation, such as may occur in the case of thrombosis and embolism, after ligation, or in consequence of the pressure of a tumour or inflammatory exudate. 2. Interruption of the efferent flow of venous blood. 3. Interruption or stasis of the circulation in the capillaries, as a result of pressure,

coagulation of the contents, or disease of the capillary walls. 4. Death of the tissue cells without any disturbance of circulation, due to poisons, such as a snake bite, or to micro-organisms and the products of their metabolism, such as are found in infectious diseases of wounds—for example, erysipelas, cellulitis, septicæmia, etc. The various causes of gangrene are frequently more or less combined—for example, abnormally high or low temperatures cause both the cells and the vessels to lose their integrity in consequence of the coagulation of the albumen. The different tissues possess different powers of resistance against the above-mentioned causes of gangrene. A loop of intestine, for example, will die if exposed for a couple of hours to a temperature of 8° to 10° C. (45° to 50° F.), while muscles or tendons will be but little or not at all affected from a similar exposure to the same influences. The brain, kidneys, and intestine undergo necrosis within one or two hours after interruption of the afferent flow of blood, while the skin and muscles can do without circulation for ten or twelve hours. The tissues present these same differences when subjected to traumatisms. The brain is very susceptible to traumatic influences, and likewise to loss of water, while the skin, connective tissue, and bone are much less so.

Local and general anæmia, venous stasis, disturbances of circulation from diseases of the vessels, heart, or lungs, or disturbance of circulation due to inflammation—in short, faulty circulation from any cause—increases the disposition to gangrene from the effects of mechanical, chemical, or thermal influences. Under these conditions, comparatively slight causes may suffice to bring about death of tissue.

Senile Gangrene.—Gangræna senilis belongs to this class of cases; it is a mortification occurring in old age and affecting the toes especially. There is usually an accompanying advanced arterio-sclerosis with chronic disturbances of the circulation, and, following some mild inflammation or slight traumatism, complete stasis takes place from coagulation of the blood in the capillaries.

Decubitus.—The bedsore, or decubitus, originates from some slight injury, particularly in patients who are paralysed; also in the course of severe febrile constitutional diseases, and in individuals with cardiac and pulmonary diseases which give rise to stases. Those regions are particularly endangered where the skin is directly superimposed upon bone, as in the region of the sacrum, the great trochanter, scapula, olecranon, and heel. Portions of the body where skin presses against skin, as in the scrotum or labia, have but little power of resistance in individuals with circulatory disturbances.

In still other instances a weak constitution—in other words, a condition in which the cells possess slight powers of resistance—favours the occurrence of gangrene. This is seen in old people with advanced arterio-sclerosis and in those who are poorly nourished.

Noma.—This is the reason why the gangrene which spreads so rapidly on the face, the so-called cancrum oris, or noma (Fig. 388), is particularly likely to develop in individuals who are very much reduced and in children after acute infectious diseases (see Regional Surgery).

Ergotine Gangrene.—Poorly nourished individuals are the ones most commonly affected by the gangrene occurring in chronic ergotism, which was

ımon in the middle ages. The disease results from the ingestion ontaining the ergot of rye. Ergotism is characterised by disorders n, by general formication, , and pains remities, etc. pidly spread- ɜne makes its e, involving ly the toes, ɜ portions of ɜmities, the ɔse, may per- main cause ɜase is prob- contractions ı the small y the ergo- is produces with subse- ıgrene, espe- ıe individual ɔurished and According ɜl, ergotine is mainly to l to the anæs- ɜed by the er- consequence injurious in- f all kinds, raumatisms, ɜrceived, and hence the individuals affected by the disease are ɔrotect themselves.

Fig. 388.—Noma in a boy seven and a half years of age, four weeks after the commencement of scarlet fever. Death on the twelfth day.

ɜne accompanying an Abnormal Composition of the Blood.—Men- l be made of the gangrene occurring when the composition of the mes altered, as in anæmia, hydræmia, and diabetes mellitus. In lisease gangrenous inflammations, particularly of the cellular tis- t to arise after the reception of slight injuries. As a result of the composition of the blood, the walls of the vessels and the cells tle power of resistance that, when subjected to any slight trauma- ection, disturbances of circulation with stasis and gangrene readily A diabetic cellulitis often runs its course without marked swelling mia, and there may be no fever. Diabetic gangrene in the vast f instances is caused by arterio-sclerosis of the vessels, as in senile Heidenhain).

ıs Gangrene.—Disturbances in the nerve supply may also favour ɜpment of gangrene. This is the explanation of the gangrene ɜing leprosy (§ 85), and also that affecting paralysed portions of

the body. Either the trophic nerves lose their integrity, or the necrosis of tissue and ulceration take place because the patients do not feel the irritations of the skin, and thus, as in ergotism, cannot avoid the injurious effects of such irritation.

The so-called malum perforans pedis, a punched-out, progressive ulceration of the sole of the foot, and the symmetrical gangrenes, are likewise due to nervous causes.

Symmetrical Gangrene.—According to Raynaud and Weiss, symmetrical gangrene usually appears in paroxysms, affecting the fingers, toes, and less often other portions of the body. This rare disease begins with paræsthesia and neuralgic pains; then cyanosis or anæmia develops in the parts which are involved in consequence of contraction of the vessels. The gangrene generally begins in the pulp of the terminal phalanx, and either remains superficial or the entire terminal phalanx perishes. Bramann saw this symmetrical gangrene develop in three brothers of seven, ten, and thirteen years of age; it was probably the result of syringomyelia. As etiological factors, chlorosis, anæmia, hysteria, acute febrile infectious diseases (typhoid, intermittent fever, etc.), or primary neuritis, come into consideration. The direct cause of this form of gangrene is to be sought probably in disturbances of the vasomotor centres in the central nervous system. The acute gangrene, originating from disease of the vessels, is certainly to be distinguished from the purely nervous symmetrical gangrene (Socin).

Spontaneous (Angioneurotic) Gangrene of the Extremities occurring in Youth.—In rare instances a spontaneous gangrene of the extremities is observed which is not due to ergotism, diabetes, or syphilis, and which, in contradistinction to senile gangrene, affects strong, young individuals who are not marasmic (Billroth, Braun, etc.). The course of the disease is very tedious and extremely painful. In rare cases spontaneous recovery has been observed, but it is generally the best plan to amputate the limb, for example, by Gritti's method, at the knee, or higher up, through the thigh. Attempts at amputation nearer the periphery, in close proximity to the gangrene, are usually hopeless. Zoege-Manteuffel and others found the causation of this spontaneous gangrene to be a high grade of arterio-sclerosis, with narrowing and thrombosis not only of the main arterial trunks in the leg, but also of the smaller veins. The lesions consist of a narrowing or closure of the vessels either by an endarteritis obliterans due to proliferation of the endothelium with hypertrophy of the muscular coat, or by organised clots in the vessels which have been formed in consequence of the arterio-sclerosis. The principal nerves are usually much thickened and swollen. This sclerosis of the vessels is probably a trophic disturbance of the latter due primarily to lesions of the nervous system. Angio-sclerotic gangrene is particularly apt to occur in cold, northern regions, such as Russia. In other cases the chronic diseases of the walls of the blood-vessels resulting in gangrene are caused by syphilis, old age, diabetes, alcoholism, lead-poisoning, etc.

Symptoms of Gangrene.—The symptoms of gangrene vary in general according to its cause and location, as well as the kind of tissue which is affected. We recognise a dry gangrene—mummification, as it is called—and a moist gangrene. In dry gangrene there is drying of the tissues as a result of a loss of water; senile gangrene is an example of this form. In such cases

the superficial layers of tissue dry and form a gangrenous eschar. The moist gangrene is a necrosis with softening and liquefaction, and consequently is the opposite of dry gangrene. Moist gangrene is particularly likely to be accompanied by decomposition. In such cases the tissues are softened and discoloured, and present bluish-red, green, or black spots; they give forth a penetrating odour, which is due to the formation of products consisting of compounds of ammonia and fatty acids. The epidermis is elevated by blebs which are filled with a stinking liquid. Not infrequently bubbles of gas develop at the same time which contain especially ammonia, volatile fatty acids, and sulphide of hydrogen. Finally the tissues break down and form discoloured, shreddy masses. This moist gangrene with decomposition is particularly apt to take place when the air with its germs has access to the parts and no disinfecting antiseptic dressing is employed, and consequently occurs most commonly in the superficial portions of the body and the cavities which adjoin, in the lungs, etc. It is only possible for this gangrene to attack other organs by metastases, which are caused by suppurating thrombi or gangrenous pus and the bacteria they contain.

The coagulation death is another form in which gangrene presents itself. It occurs especially in necrosis of the muscles or other tissues made up of cells containing protoplasm which is capable of coagulation. According to Cohnheim and Weigert, it is dependent either upon a chemical precipitation of an albuminate or upon coagulation of the albumen by the action of a ferment which is set free. Coagulation necrosis occurs particularly in diphtheria, croup, and in the tissues surrounding colonies of bacteria.

Cohnheim states that necrosis very seldom results from the action of moulds, for the reason that the mould fungi and the bacteria of decomposition do not exist under the same conditions. A medium which supports the bacteria of putrefaction is unsuitable for mould fungi. The latter, for the most part, are incapable of development in the living body, and soon disappear (see pages 257–259).

Other symptoms of gangrene are a loss of function in the parts affected, their insensibility, and the cool or cold feeling which they exhibit on palpation.

The microscopic changes in the dead tissues vary with the form of the necrosis—that is, whether they become dry or undergo putrefaction. In the above-mentioned coagulation necrosis of Weigert the cell nuclei disappear first. The nuclei are dissolved by the lymph, and the substance of which they consist perhaps unites with the albuminous constituents of the lymph. This phenomenon is similar to the coagulation of fibrin. The dead cells also exhibit a diminution in the size of the nuclei, vacuolar degeneration, swelling of the protoplasm of the cell, and a merging of the borders of the cells into the surrounding parts.

As regards the course of the gangrene, it either remains limited to a particular region, or it spreads. The gangrene following an interruption of the circulation or some direct traumatic disturbance of the tissue elements in an otherwise healthy individual, ordinarily remains circumscribed unless the gangrenous focus becomes infected by bacteria. On the other hand, if the health of the individual or of the affected portion of the body is faulty, the

gangrene may spread (decubitus, senile gangrene, diabetes mellitus). The gangrene, in particular, which follows the development of bacteria, very prone to spread (see pages 339–344). The boundary of the necrosed tissue is formed by the so-called line of demarcation—that is, by a demarcating inflammation and suppuration—by which the living are separated from the dead parts. A loss of substance takes place—in other words, an ulcer of the skin, the surface of the ulcer being the seat of a suppurative inflammation. This ulcer gradually purifies itself and cicatrises by the formation of granulation tissue. Not infrequently when the dead tissue is cast off, some cavity of the body is opened, and death follows. Thus, for example, perforation of the intestine or stomach by an ulcer may give rise to fatal peritonitis, and caries and necrosis of the petrous portion of the temporal bone may cause suppurative meningitis or a cerebral abscess. Other dangers of gangrene are the occurrence of hæmorrhage from the erosion of an artery, and the development of some secondary infectious-wound disease, particularly pyæmia and septicæmia, from infection by micro-organisms and the products of their metabolism.

The treatment of gangrene is conducted according to the rules laid down in §§ 70, 88, and 90 to 93, to which we must refer the reader. In gangrene of the extremities, amputation should not be performed too near the gangrenous parts—a matter which has been insisted upon before. Should a gangrene of the foot, for example, involve the dorsum or sole, Gritti's operation should be given the preference, or amputation at the thigh, because, if the leg is amputated below the knee, extensive gangrene of the flaps almost always occurs. Occasionally, however, amputation two to three fingers' breadth above the gangrene is followed by good results (König, Landow).

CHAPTER III.

INJURIES AND SURGICAL DISEASES OF BONE.

Injuries of bones: Fractures; contusions and wounds of bone; gunshot injuries of bone (see also § 124).—The inflammations and diseases of bone: Acute inflammations of bone; acute periostitis; acute osteomyelitis; acute ostitis.—Metastatic inflammations of bone.—Embolic foreign-body inflammations in mother-of-pearl turners and workers in woollen and jute mills.—The chronic inflammations of bone (tuberculosis, syphilis, etc.): Chronic periostitis, osteomyelitis, and ostitis.—Caries.—Necrosis of bone.—Spontaneous separation of an epiphysis.—Rhachitis.—Osteomalacia.—Atrophy and hypertrophy of bone.—Increased longitudinal growth.—Giant growth.—Acromegaly.—Tumours of bone (see Tumours, Chapter V).—Parasitic tumours of bone (echinococcus; *cysticercus cellulosæ*).

§ 101. **Fractures.**—The word fracture needs no further definition; it means both the act of breaking a bone and the state of being broken. Fractures are very common, and, according to Bruns, they make up more than a seventh part of all injuries which come under observation, and are about ten times as common as dislocations.

Causes of Fractures.—Every fracture presupposes the action of some mechanical violence upon the bone in question which is great enough to overcome the strength and the power of resistance which the bone possesses. The majority of fractures are produced by external violence; and, according to the way in which the external violence acts, we distinguish two main groups, the direct and the indirect fractures.

Direct and Indirect Fractures.—The *direct* fractures are those in which the bones are broken at the point where the violence, such as a blow, a thrust, a gunshot, the wheel of a wagon, etc., is applied. If, on the other hand, the break is situated at a point some distance from the place where the violence has been applied—in a fall, for example—we call such a fracture an *indirect* one. It is evident that in the direct fractures especially the soft parts will receive more or less injury, which varies from a slight contusion to a complete mangling of all the soft parts surrounding the broken bone. The indirect fractures are most commonly the result of a bending of the bone beyond the limits of its elasticity by bringing the two ends of the bone nearer together, as in a fracture of the thigh from a fall upon the feet. In other

instances indirect fractures are the result of forced compression and crushing, as in fractures of the vertebræ from a fall upon the buttocks; or of violence applied through a fulcrum with crushing, as in fracture of the olecranon by hyperextension at the elbow joint; or of traction, tearing, or rotation (torsion). The lower end of the radius, for example, is caused to break by the traction exerted by the anterior ligament of the wrist in forced dorsal flexion. Great interest attaches to the production of indirect fractures of the skull by a tearing apart of the portions which are put on the stretch, or by the vertebræ being driven into the occipital foramen (Messerer). In indirect fractures it sometimes happens that the fragments are more or less firmly forced into one another (so-called impacted fractures). The injuries to soft parts occurring in indirect fractures are produced by more or less pointed fragments which perforate the skin (transfixion fractures), or wound muscles, vessels, or nerves, etc.

Fractures resulting from Muscular Action.—Sometimes fractures are the result of excessive muscular action. These usually take the form of a tearing off of some small bony prominence, like the coracoid process of the scapula, or the greater tuberosity of the humerus. The fractures, which often complicate dislocations, are frequently produced in a similar manner; for example, the ilio-femoral ligament may tear off a piece of bone from the femur at its point of attachment (cortical fracture). It only rarely happens that large, hollow bones are broken by muscular traction. In this category come the fractures of the femur sustained in playing at ninepins, or in administering a kick which misses its object; also fractures of the humerus from violent movements of the arm, transverse fractures of the patella (see Regional Surgery), and fractures of the clavicle from brandishing a whip, or fractures of the ribs as a result of violent attacks of coughing in old people, etc.

Intra-uterine Fractures.—Intra-uterine fractures in the fœtus are produced by the infliction of great violence to the abdomen of the mother. Varying with the length of time which elapses between the reception of the injury and the birth of the child, the fracture will be found to be comparatively recent, in process of repair, or already healed. The bending or fracture of bones due to fœtal rhachitis or syphilis are not of traumatic origin. Other intra-uterine bony deformities are also met with which at first sight look like badly united intra-uterine fractures, but are, in reality, defects in development. In this class of cases belong the malformations which are the result of defects in ossification, such as absence of the fibula, etc.

Fractures during Birth.—In other instances infants sustain fractures during birth from unskilful operative midwifery or from the act of parturition itself. The bones of the extremities may be broken through the diaphy-

sis or in the region of the epiphysis while an arm is being freed or version or extraction performed, but fractures of the bones of the head are mainly due to the use of the forceps. In very rare cases fractures of malposed extremities result from contractions of the uterus. The latter are more likely to cause injuries to the skull, especially in cases of narrow pelvis or anomalies of the child's head. In the milder cases there will be a depression with or without fissure, while in severe cases actual fractures of the skull occur.

The amount of resistance of which a bone is capable bears a very important relationship to the production of fractures. The strength of a bone varies greatly in different individuals, as does also the strength of different bones in the same individual, and even different parts of the same bone exhibit variations in resisting power.

Natural Solidity of the Bones.—The natural strength and mechanical capabilities of bones, so important in the etiology of fractures, have recently been investigated by P. Bruns, Reiff, and others, and the attempt has been made to found the etiology of fractures upon a physical basis. The elasticity of the individual bones—i. e., their ability to resume their original shape after it has been changed by external force, and the limits within which this is possible—in other words, the limit of their elasticity—have been computed. The strength or the resistance which the bones offer to violence in its various forms, such as pressure, traction, bending, rotation, or torsion, had also been ascertained. It has thus been possible to determine definite values for the elasticity and solidity of the texture of the bone substance, and for the bones in their entirety, which values express the amount of this or that kind of violence required to produce fractures; and hence it is perfectly correct to designate fractures according to the nature of the traumatism, as fractures from traction or tearing, from compression, bending, or torsion.

Measurements showing the Strength of Bones.—As regards the strength of a bone due to its structure, the values naturally vary in different bones and in different individuals, but the general rule holds that the compact bone substance is always stronger than the spongy.

The tensile strength of the compact bone substance in a fresh condition and during middle life amounts, according to Rauber and Messerer, to 9.25 to 12.21 kilogrammes per square millimetre, or about the same as that of brass and cast iron. The compression strength is still greater (12.56 to 16.8 kilogrammes per square millimetre), or double that of wood, granite, or lead. The torsion strength averages 8 kilogrammes per square millimetre.

The strength of spongy bone substance is much less, the compression strength of the spongy portion of the femoral condyles amounting, according to Messerer, to only 0.96 kilogramme per square millimetre, that of the bodies of the vertebræ to 0.84, being in middle life 0.62 to 0.92, and in old age only 1.22 kilogramme per square millimetre.

The strength of the bone as a whole is a matter of great practical importance as regards the etiology of fractures. The tensile strength of the hu-

merus, for example, according to Messerer, amounts to 533, and of the femur to 694 kilogrammes per square millimetre. He found that the compression strength of the individual bones decreased in the following order: Tibia, femur, humerus, radius, ulna, clavicle, fibula. Compression directed through the longitudinal axis caused fracture of the shaft, the tibia being the strongest and breaking under a pressure of 1,650 kilogrammes, the femur on the average in man requiring a pressure of 756 kilogrammes, the radius in man 334 kilogrammes, in women 220 kilogrammes. Frequently the break does not take place at the point most endangered—the middle of the bone—but at one or other articular extremity by compression.

A great number of fractures are, as is well known, the result of bending (Bruns). The limit of bending possessed by bones varies in different years of life, and, according to Messerer, it amounts to between 1,040 and 1,980, and reaches its maximum at middle age. In men 400 kilogrammes, and in women 263 kilogrammes, will cause a fracture of the femur from bending.

The torsion elasticity amounts to about a third of the bending elasticity. A fracture of the femur by torsion, according to Messerer, is produced by 89 kilogrammes, of the clavicle by 8 kilogrammes. The femur possesses the greatest torsion strength, the clavicle, ulna, and fibula the least.

Messerer's experiments on the skull show that the diameter, which is not subjected to pressure, becomes, in the majority of instances, gradually though very slightly lengthened in proportion as the pressure increases. The decrease of the diameter in the direction of the pressure is not evenly distributed over the whole skull, as only the part directly subjected to pressure bends inwards. The skull withstands a greater amount of force in a sagittal than in a transverse direction. The pressure required to produce a longitudinal fracture averaged 650 kilogrammes; for a transverse fracture, 520 kilogrammes. In most instances the base of the skull proved to be the weakest spot, that portion of it bursting which was under the greatest tension; transverse pressure caused a transverse fracture, and longitudinal pressure a longitudinal fracture. The average pressure, acting through the vertebral column, which was required to produce a fracture of the base amounted to 270 kilogrammes.

In young persons the sternum could be driven completely back to the vertebral column by sagittal pressure upon the thorax without producing a fracture. A pressure of 250 kilogrammes exerted in a sagittal direction upon the pelvis generally caused a symmetrical fracture of the os pubis; a transverse pressure of 180 kilogrammes exerted upon the crest of the ilium caused a diastasis of the sacro-iliac joint.

According to Rauber, the strength of bones is, as a general thing, diminished by heat.

Changes in the Strength of the Bones.—The normal strength of bones is affected very materially by various circumstances, such as their shape, their length and thickness, the direction of their longitudinal axes, whether the latter approach the perpendicular or show deviations from it, etc. There are also various pathological conditions which lessen the resisting powers of bones and produce an abnormal fragility

(osteopsathyrosis), causing the bones to break spontaneously or upon the application of a very slight amount of violence. In this category belongs the atrophy of bone which occurs in advanced age, or in the course of chronic diseases, or after paralysis, etc. The strength of the bones usually increases till middle life, and from then on gradually decreases (senile atrophy). The bones also atrophy when they are not used, as in the course of chronic diseases, in paralysis, etc. (atrophy of disuse).

Neurotic or Trophoneurotic Atrophy.—In addition to the atrophies of senility and disuse, Weir Mitchell, Charcot, and P. Bruns have directed attention to the occurrence of neurotic or trophoneurotic atrophies of bone which are due to affections of the central nervous system. In this class of cases belongs the fragility of bone which accompanies tabes dorsalis and chronic cerebral disease, such as progressive paralysis, and in fact all forms of mental disease and paralysis. Rauber found that the tibia of a paralysed extremity weighed 198 grammes, while the bone on the non-paralysed side weighed 281 grammes. Nasse, Schiff, and others have seen very different effects upon the bone follow division of the sciatic nerve in animals; in some instances there was a lengthening, in others a thickening and increased weight, and at other times marked flexibility and diminution of the specific weight. Ghellini found that in rabbits which were given their freedom division of the sciatic was followed by shortening of the paralysed leg, while lengthening took place in those kept in a cage—probably on account of the diminished pressure.

No further explanation is required for the fragility which is the result of disease of bone with subsequent loss of substance, such as occurs, for example, in tubercular and syphilitic diseases, suppuration, or necrosis; tumours, such as cysts, sarcoma, or carcinoma; from the presence of echinococcus; or abnormal softness of structure (rhachitis and osteomalacia). An abnormal weakness and fragility of the bones is also present in scurvy, a disease which was at one time very common.

Idiopathic Osteopsathyrosis.—But in addition to these various kinds of fragility of bone due to this or that cause, there is also an idiopathic form, the etiology of which is as yet completely unknown. In such patients, who in all other respects seem perfectly well, the slightest exhibition of violence, such as a sudden movement, a slight thrust, or even turning over in bed, suffices to produce a fracture of bones which externally appear entirely normal. The malady is congenital in a number of cases, and sometimes a pronounced hereditary taint runs through many generations. In other cases the disease develops in early youth or later, and then usually persists throughout life. In

this idiopathic form of fragility no gross changes are found bones. The most probable cause of this disturbance of the nı of the bones is a change in the composition of their ground sub The observations of Blanchard, in particular, show the freque fractures in individuals with idiopathic fragilitas ossium. He h case of a twelve-and-a-half-year-old girl who had had, since the month of her existence, forty-one fractures from the effects c slight violence; she had had fourteen fractures of the right and of the left leg. Arnott had a patient fourteen years old who si third year of life had had thirty-one fractures, of which seven v the right thigh and nine of the right leg below the knee. It is remarkable that the repair of fractures in idiopathic osteopsat usually takes place easily and quickly.

Strength of the Epiphyses.—As long as the diaphysis and the ysis, during the period in which the bones are growing, are cor by a cartilaginous symphysis, the resistance at this point may be ished by various processes, especially those of an inflammatory and a spontaneous separation of the epiphysis may thus be pr Under this heading come the epiphyseal separations due to sy processes, to scurvy, and to the primary infectious inflammations medulla (osteomyelitis).

The Various Kinds of Fractures—Incomplete Fractures, Dep Fissures.—We distinguish complete and incomplete fractures ac to the extent to which the bone is divided. To the incomplete fr belong the green-stick fractu the fissures. A green-stick f occurs in the bending of a b which the cortical substance convex side is broken while concave side it is only pre

Fig. 389.—Incomplete fracture (green-stick fracture) of the clavicle.

(Fig. 389). The depressions occurring on the skull, for examp result of pressure or a blow, can be regarded as incomplete fr (Fig. 398). The fissures (Fig. 390) are comparable to a crack in or a plate, and occur especially in the brittle bones of adults, les in those of children, and are frequently combined with complet tures which are received at the same time. They are particularl mon on the skull. In gunshot fractures the bones involved oft tain numerous fissures. It is of great practical importance to no fissures of this description, especially when the fracture is near sometimes run through the articular extremity of the bone an trate into the neighbouring joint. If after a gunshot fractu example, suppuration should take place at the point where th

as been broken, this suppuration may travel along the fissure into ie joint.

Complete Fractures.—A fracture is complete when the bone breaks to two or more pieces which are completely separated from one iother; division of the bone into two fragments takes place most commonly. According to the direction of the line of fracture with reference to the longitudinal axis of the bone we recognise transverse, oblique, spiral, and longitudinal fractures. The pure transverse fractures are generally produced by direct violence, and are not

Fig. 390.—Fissures in the femur.

Fig. 391.—Fracture having the shape of the mouthpiece of a flute (*fracture en bec de flûte*).

ry common if we disregard the separations of the epiphyses. The ost common fractures are the oblique, which are almost always the sult of indirect violence, i. e., forcible bending. The fracture having e form of a clarinet mouthpiece, and first described by French writers *racture en bec de flûte*), is a pronounced oblique fracture which occurs pecially in the tibia and femur, and was produced by W. Koch by tation combined with a vertically directed blow (Fig. 391). The iral or torsion fracture (Figs. 392, 393) is produced, according to the periments of Koch and Bruns, exclusively by twisting, the line of icture having the shape of a spiral curve. The prognosis of a spiral cture is more unfavourable than an oblique one, for the reason that fractured surfaces are very extensive and the points of one of the gments may readily penetrate the skin or be driven into the other gment and cause considerable crushing of the bone marrow.

Longitudinal Fractures.—Longitudinal fractures, or the division of one into two fragments with the line of fracture running its entire

length, are very rare in the long, hollow bones, and most longitudinal fractures are merely extreme forms of oblique fractures. Krönlein has described a longitudinal fracture of the humerus and three longitudinal fractures of the phalanges of the fingers, and he could find in literature only one longitudinal fracture through the whole length of the tibia, which was recorded by Gädücke. Longitudinal fractures have been noted somewhat more frequently in the short bones (patella, vertebræ).

Fig. 392.—Spiral fracture of the tibia (W. Koch).

Fig. 393.—Spiral fracture of the femur (W. Koch).

A Multiple Fracture.—In a multiple fracture (fractura multiplex) the bone is either broken at two or three different points (double, threefold fracture), or the bone is shattered at one point into many fragments (comminuted fracture). The term multiple fracture also includes fractures sustained simultaneously by several bones, particularly those which are placed parallel to one another in the forearm and leg. The shape of the multiple breaks in the same bone varies, of course, very much, but a few typical forms are frequently observed. These typical forms include especially the T-and Y-shaped fractures, occurring at the epiphyseal extremities of the long bones (Figs. 394, 395). In the T fracture (Fig. 394) there is a transverse and a longitudinal break; in the Y fracture two oblique breaks, the production of which has been studied experimentally by Gurlt, Madelung, and Marcuse. In fractures from bending and from torsion a cuneiform or rhombic piece is sometimes broken out of the continuity of the bone (Bruns). The outward appearance of a comminuted or splintered fracture (Fig. 396) presents great variations in regard to the number, shape, and size of the individual fragments. In the

worst cases there will be found at the point of fracture a peculiar soft bag of skin like a sac filled with crepitating fragments of bone, or the bones and soft parts are crushed into a bloody pulp, as is the case, for example, in "run-over" accidents.

Condition of the Soft Parts in the Neighbourhood of a Fracture.—The condition of the soft parts in the neighbourhood of a fracture is exceedingly important for the prognosis. All fractures in which there is a wound of the soft parts penetrating to the line of fracture are called compound or open fractures, and must be carefully distinguished from the subcutaneous or simple fractures—i. e., those in which the outer covering of the soft parts has not been opened. In the days before antisepsis the compound or open fractures very often terminated fatally from pyæmia and septicæmia. The extent of the wound of the soft parts varies from an insignificant puncture to an extensive crushing and laceration of the tissues. The wound is produced either by the same violence that produces the fracture, as in gunshot or run-over injuries, or the skin is opened afterwards by injudicious movement of the fractured extremity—in transportation of the patient, for example—or as a result of gangrene, etc. The open, comminuted fractures, the compound fractures of joints, particularly those found in gunshot wounds, and extensive mangling of the bones and soft parts in run-over accidents, are the most unfavourable compound fractures.

Separations of the Epiphyses.—In young subjects, as long as the diaphysis and epiphysis are connected by a cartilaginous symphysis,

Fig. 394.—T-shaped fracture of the lower end of the femur, caused by a fall upon the knee (Bruns).

Fig. 395.—Y-shaped fracture of the condyles of the humerus, caused by a fall upon the elbow (Bruns).

Fig. 396.—Comminuted fracture of the lower end of the humerus, caused by a fall upon the elbow.

traumatic separations of the epiphyses may occur, which, according to Bruns, are most common in the case of the lower epiphysis of the femur, then in the lower epiphysis of the radius and in the upper epiphysis of the humerus. The *spontaneous* separations of the epiph-

yses in consequence of inflammatory or suppurative processes must be carefully distinguished from the traumatic separations. The traumatic separations are mainly the result of exaggerated movements in joints. As a result of these exaggerated movements in adults, dislocations of the joints take place, but in children fractures through the fragile epiphyseal cartilage or in its neighbourhood. This is the reason why traumatic dislocations are so very rare in young children. In infants, separations of the epiphyses, particularly *inter partum*, are brought about by violent or unskilfully performed obstetrical operations (version, extraction). The age limit within which epiphyseal separations may occur varies with the different epiphyses. The observations hitherto recorded, for example, show that the twenty-fifth year of life is the latest period at which a traumatic separation occurs in the upper epiphysis of the humerus.

Symptomatology and Clinical Course of Fractures.—The symptoms of fractures are partly objective and partly subjective. The most important objective symptoms are: 1. Abnormal mobility of the bone. 2. Crepitus—i. e., the rubbing sound which is heard, or, more correctly, felt, when the fractured surfaces are rubbed together. 3. Deformity of the broken bone, or rather of the part of the body to which it belongs, in consequence of the displacement of the fragments. Abnormal mobility and crepitus are best demonstrated by seizing both fragments in the neighbourhood of the line of fracture and moving them in opposite directions. Rotary movements may also be tried in cases of fractures of the articular ends of bones. Abnormal mobility and crepitus are absent in impacted fractures, in fractures with sharp, toothed fragments which interlock, and in incomplete fractures. Crepitus will also be absent when the fractured surfaces are not in immediate contact with one another. The soft friction sound which is sometimes emitted by dried extravasations of blood or by inflammatory processes—of the tendon sheaths, for example—must be carefully distinguished from the harder bony crepitus. Deformity is caused by the displacement of the fragments. We recognise the following four principal kinds of dis-

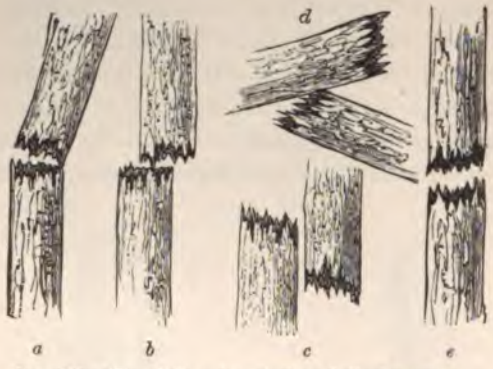


Fig. 397.—The different varieties of displacement.

, which sometimes occur separately and sometimes combined
ways: 1, Angular displacement (dislocatio ad axin, Fig.
2, lateral displacement (dislocatio ad latus, Fig. 397, *b*);
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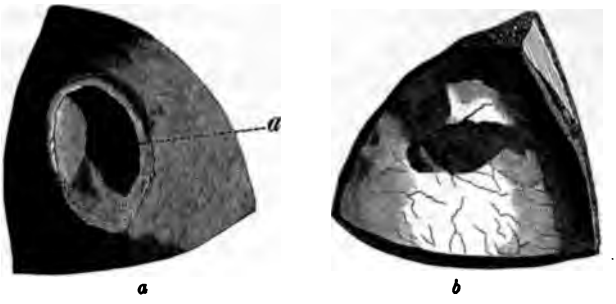


FIG. 398.—*a*, Fracture of the skull with depression, seen from the outside (caused by a fall upon a pointed stone); *b*, the same fracture seen from within (Bergmann).

e pushing of one over the other (Fig. 397, *d*)—is a combina-
e dislocatio ad latus and ad axin, sometimes with the addition
catio ad longitudinem. The so-called diastasis of the frag-
g. 397, *e*) and the reverse or impaction of the fragments are
arded as a dislocatio ad longitudinem. There is a variety of
ent, occurring mainly in fractures of the skull, which is called
of the fragments (Fig. 398, *a*, *b*).
ifferent displacements are sometimes primary and produced
cturing force, and at other times secondary, occurring sooner
fter the injury as a result of voluntary or involuntary muscu-
ctions, of transportation, examination, the position the injured
caused to assume, of defective dressings, etc.
tive Symptoms of Fracture—Pain and Disturbance of Function.
jective symptoms of fracture are pain and disturbed function.
and tenderness on pressure are most marked directly at the
racture. Above and below the line of fracture the bone is
tender on pressure. This linear character of the pain, so to
of great diagnostic importance in doubtful cases.
isturbance of function which occurs in fractures needs no fur-
anation. In consequence of the division of the bone, an
, for example, loses its bony support, and the muscles their
ts of attachment. The amount of functional disturbance
rincipally upon the amount of the abnormal mobility, dis-
t, and deformity, and also upon the nature and location of the
If, for instance, only one bone is broken in a limb which
wo, the functional disturbance may be very slight, varying

with the importance of the broken bone. Thus in fractures of the fibula the patient will still be able to walk, and in fractures of the ulna use of the forearm is possible, especially pronation and supination. The disturbance of function is also slight in the case of impacted fractures, and patients with an impacted fracture of the neck of the femur can stand and walk. Moreover, in impacted fractures of the articular extremities of other bones the movements of the joint involved are often very little or not at all disturbed.

Fever in Simple Fractures.—Apart from these local symptoms at the point of fracture, we sometimes observe fever following the reception of subcutaneous fractures. The thermometrical measurements made by Volkmann, P. Bruns, Grundler, and myself, show that, as a rule, more or less fever exists, particularly during the first few days after the injury. The height of the fever varies between 101.3° and 102.2° F., though in rare instances the temperature may rise to 104° F. In twenty-five out of twenty-six cases of subcutaneous fracture Grundler observed a rise of temperature to 99.1° F. The cause of this febrile movement is ascribed by Bergmann, Wahl, and Angerer to the absorption of dead tissue elements, and especially of fibrin ferment and other ferments which are formed in the extravasated blood near the point of fracture, as described in § 62. The fever is essentially a ferment intoxication.

Suppuration in Simple Fractures.—As a rule, subcutaneous fractures heal without suppuration, and the latter only occurs when micro-organisms gain access to the point of fracture through some small cutaneous wound or through the blood; the extravasated blood and the injured (necrotic) tissues furnish a favourable nutritive medium for their development.

Course of Compound Fractures.—The course of compound fractures varies greatly, according to the size of the wound in the soft parts, the condition of the fragments, and the treatment. The favourable cases are those with a small cutaneous wound, which, before infection occurs, heals by immediate adhesion of the opposed wound surfaces, or beneath a scab *per primam intentionem.* Under these conditions they run a course like that of a subcutaneous fracture.

The worst cases of compound fractures are those in which the soft parts are so extensively destroyed that the preservation of the limb is entirely out of the question. To these may be added the cases in which there is extensive splintering of the bones or a perforation into a joint or one of the cavities of the body. But as a general thing it is more the extent of the injury to the soft parts than the severity of the injury sustained by the bones which determines the gravity of the

case. Any simple division of the bone which is accompanied by great destruction of soft parts is to be regarded, in point of prognosis, as a more severe injury than a splintering of bone which is in itself considerable but is not accompanied by any great amount of injury to the soft parts.

The clinical course of a compound fracture is, moreover, affected in a very marked degree by the way in which it is treated. The sooner a compound fracture is placed under the protection of antiseptic treatment—i. e., the sooner the wounded soft parts and the seat of the fracture are thoroughly disinfected, the drainage of the wound attended to, and an antiseptic dressing applied—the sooner is a satisfactory course of repair guaranteed.

If we leave out of consideration those compound fractures which heal aseptically and without any reaction, the local symptoms, in the majority of cases, consist in a more or less severe inflammatory swelling in the parts surrounding the wound and point of fracture. The discharge from the wound is at first thin and discoloured by blood. In the aseptic cases it is limited in amount and does not become suppurative. In the cases which do not run an aseptic course the discharge is plainly purulent or even sanious—in other words, it undergoes decomposition in consequence of infection by micro-organisms. The production of suppuration and putrefaction is favoured by extensive destruction of the soft parts at the time of the injury. This putrefactive suppuration can, if the escape of the discharge is prevented, readily take on a spreading character in the shape of a progressive gangrenous cellulitis, which may endanger the preservation of the limb and of life. If the suppuration or putrefaction runs a favourable course, the surface of the wound gradually "purifies" itself—i. e., the superficial gangrenous portion of the wound is slowly cast off by a demarcating suppuration, red granulations make their appearance, and the wound fills with germinal tissue which then ossifies. The suppuration around the ends of the fragments which have become necrotic, or around splinters, is sometimes very tedious, and there is always the possibility of the pus burrowing or giving rise to infectious suppuration in the periosteum or the bone marrow, or causing lymphangitis, phlebitis, etc., and thus death from septicæmia or pyæmia. By long confinement to bed, or from protracted fever or profuse suppuration, the patient may become so exhausted and such serious degenerations of the internal organs may occur, that life is imperilled.

Throughout the entire period occupied by the process of repair, the temperature of the patient should be taken two or three times a day, and at every new rise of temperature the wound should be carefully exam-

ined to determine the presence of any disturbance, such as a burrowing of pus, a deeply located spreading inflammation and suppuration, etc.

Not infrequently, after a compound comminuted fracture has healed fistulæ will persist for a long time; they indicate the presence of some encapsulated, necrotic piece of bone—a so-called sequestrum.

Condition of the Urine in Fractures.—As a result of the absorption of blood from the point of fracture, the urine very frequently contains urobilin, a derivative of the colouring matter of blood, which, on shaking the urine with a solution of chloride of zinc and ammonia, causes the urine to assume a yellowish-green fluorescence. Fat is also very often found in the urine; it is derived as fluid fat from the crushed medullary portion of the bone and the fat in the neighbouring soft parts, and, passing through the circulation, is excreted by the kidneys. We shall learn further on that it can sometimes accumulate to a dangerous degree in the lungs and brain. The amount of fat in the urine varies greatly, depending upon the severity of the injury to the marrow and soft parts; in some cases it is found only in traces, while in others there may be large quantities of it. Occasionally it is so abundant that it is visible in the form of smaller or larger drops on the surface of the urine. Most commonly the fat is mixed with the urine in the form of an emulsion, and Scriba maintains that this occurs in almost every case of fracture. After the urine has been allowed to stand for some time a white layer develops on its surface, which the microscope shows is made up of small and minute fat drops. According to Scriba, the excretion of fat by the kidneys takes place periodically, corresponding to the sweeping away of the fat emboli in the lungs. This is the reason why the urine during the repair of a fracture changes so much, containing fat for several days and then being free from it for five to six to ten days. The excretion of fat begins on the second to the fourth day after the injury, and usually ceases on the twentieth to the twenty-fourth day.

In addition to fat, the urine of patients with fractures sometimes contains albumen and casts. The amount of albumen and casts is greatest in the first twenty-four to forty-eight hours, and the condition lasts about four to six days. Besides hyaline casts Riedel found other casts studded with numerous brown granules like those which occur in bilious pneumonia and other diseases accompanied by degenerative changes in the blood. These brown casts are irregular in their occurrence in fractures and are frequently entirely absent, while in other instances they appear in great numbers. Riedel ascribes the origin of these brown casts to the absorption of red blood-corpuscles at the point of fracture. They are obtained experimentally by producing fractures artificially, by injecting blood into the peritoneal cavity, and by injecting Köhler's fibrin ferment. Both Orth and myself have occasionally found very large collections of red corpuscles and of the colouring matter of blood in the lymph glands and in the internal organs. The hæmatogenous jaundice which sometimes occurs is similarly explained by the presence of disintegrated red corpuscles and blood-colouring matter in the circulation.

Repair of Fractures.—Fractures either heal *per primam* or *per secundam intentionem*, in the same way as described in § 61 for wounds

of soft parts. Simple fractures, as a rule, heal *per primam intentionem*, while compound fractures heal *per secundam intentionem*. As we remarked above, suppuration takes place in exceptional cases of subcutaneous fractures from the entrance of micro-organisms through an abrasion of the skin or by means of the circulation.

Whether a fracture heals with or without suppuration, the anatomical changes are essentially the same, and consist, briefly speaking, in the formation at the point of fracture of cellular tissue, which is at first soft, and later is gradually changed into bone by the ossifying action of the periosteum and marrow. The ossifying tissue at the point of fracture is called the *callus*.

Anatomical Changes in the Formation of the Callus.—The anatomical changes which take place in the formation of the callus are histologically an ossifying periostitis and osteomyelitis. The extravasated blood at the point of fracture plays no active part in the formation of the callus, and is gradually supplanted by a germinal tissue rich in cells and vessels. The outer or periosteal callus originates from the inner layer of periosteum, which contains osteoblasts, while the marrow forms the inner or medullary callus (Fig. 399). The callus between the broken ends of the bone is called the intermediary callus, and is mainly produced by growth of the periosteal germinal tissue between the fractured surfaces; the tissue of the opened Haversian canals and the marrow only shares to a slight extent in the formation of the intermediary callus. The view which formerly prevailed—namely, that the surrounding soft parts were capable of contributing to the formation of the outer callus—is untenable in the light of our present knowledge of the normal development of bone.

Fig. 399.—Longitudinal section through a fracture of the femur three weeks old: *P*, periosteum; *K*, bone; *M*, medulla. Periosteal callus and medullary callus. The intermediary callus consisting of periosteal granulation-tissue, which is ossified only in some places and is partly cartilaginous.

The Normal Formation of Bone—The Development of Bone.—It is now generally believed that the normal development of bone is mainly the result of successive appositions of bone substance due to the activity of the medullary tissue, the cells of which change into specific bone-forming cells—the so-called osteoblasts (Gegenbaur, Fig. 400).

The medullary tissue may spring either from the periosteum or from cartilage. The periosteum or perichondrium (in the cartilaginous bones of

the embryo) is made up of two layers, an outer fibrous layer and an inner layer of osteoblastic cells. In this latter layer medullary spaces develop, and in them the osteoblasts from an active formation of cells and growth of vessels. In addition to the periosteal or perichondrial bone formation we recognise an endochondrial bone formation in the cartilage of embryonic bone; this takes place especially in the growth of the long bones at the epiphyseal junction. Medullary cavities develop here also, and a portion of the medullary cells change into osteoblasts. Opinion differs as regards the importance of the cartilage cells in the endochondrial formation of bone, Virchow and others believing that the cartilage cells change into medullary cells and osteoblasts, while Gegenbaur and Strelzoff maintain that the cartilage cells, as such, perish, and take no part in the formation of bone. The latter authorities hold the view that the osteoblasts are always derived from the marrow or the osteoblastic layer of the periosteum. The formation of bone from the medulla takes place in the same way as from the periosteum and cartilage. Aseptic foreign bodies, particularly absorbable pieces of bone that contain calcium, favour bone regeneration and bone formation (Barth, Neuber, and others). Maas's view that the colourless blood-corpuscles are capable of forming the callus seems to me untenable.

FIG. 400.—Periosteal formation of bone from osteoblasts, *a*; *b*, newly formed bone; *c*, old bone. × 300.

The transformation of the osteoblasts into bone tissue is brought about by a change of the greater part of the protoplasmic material into a tissue which appears homogeneous, but is really made up of fine fibrils, which, after taking up bone salts, forms a lamellated ground substance. Here and there cells persist as bone cells, which are enclosed by the newly formed bone in serrated cavities, having fine processes radiating from them. These are the so-called bone-corpuscles. Meyer and the mathematician Cullmann were the first to show that the bony structure and trabeculæ are arranged according to mechanical laws.

Interstitial Growth of Bone.—In addition to this appositional growth of bone from the periosteum and medulla, Ollier, Virchow, and others have called attention to the occurrence of an *interstitial* growth—i. e., an expansion of the bone substance already formed. This was demonstrated by driving pegs and boring holes into growing bone.

Artificially Increased Growth of Bone.—Under such pathological conditions as necrosis, chronic inflammatory processes, compound fractures, chronic joint inflammations, etc., as a result of irritation of the epiphyses, an increased growth of bone is observed, especially in the long axis. The longitudinal growth can be artificially increased and shortening compensated for by driving ivory pegs into the bone, or tying off the extremity with an elastic tourniquet, or by other forms of irritation acting upon the diaphysis in the neighbourhood of the epiphysis, from which the effects are

transmitted to the epiphyseal cartilage (Ollier, Langenbeck, etc.). In the case of a compound fracture which healed slowly with suppuration, I saw a shortening of eight centimetres in the beginning changed to three centimetres in the course of about one to one and a half year as a result of an abnormal stimulation of the growth. Sometimes, even in subcutaneous fractures, the shortening which may exist at first disappears after a year or two by augmented longitudinal growth.

Absorption of Bone Substance.—Simultaneously with the new formation of bone there is constantly taking place, on both the outer and inner surface of the bone, an absorption of the bone substance which is brought about by special cells called osteoclasts (Kölliker). These osteoclasts (Fig. 401) usually have the appearance of polynucleated giant cells, and, according to Kölliker, are derivatives of the osteoblasts; but Wegner maintains that they are formed by proliferation of adventitia cells, and Recklinghausen, that they originate from white blood-corpuscles. According to Pommer, the cells of the adventitia of the blood-vessels, the endothelial cells of the perivascular lymph spaces, and of the Haversian blood-vessels themselves—in short, the protoplasm of all the cells lying near the bone substance—are capable, under certain conditions, of taking on osteoclastic functions. Pommer states that the subsequent history of the osteoclasts, as well as their derivation, varies, and that osteoblasts or other cells may be made from them. He ascribes the cause of the production of the osteoclasts to the increase in the local blood pressure. The action of the osteoclasts is entirely local, the bone disappearing in the form of small pits or lacunæ (Howship's lacunæ, lacunar bone resorption, Fig. 401). The osteoclasts probably form carbonic acid, by which the lime salts are dissolved, and the rest of the ground substance is assimilated by the osteoclasts or absorbed by the blood or lymph current.

The Ossification of the Callus.—The ossification of the callus takes place in precisely the same way as in the development of bone. The germinal tissue either ossifies as such, or there is first a production of hyaline or fibrous cartilage. In the deepest layers of the periosteal germinal tissue, and hence close to the bone, at a little distance from the broken ends and in the neighbourhood of the normal intact periosteum, there appear by the third or fourth day small collections of bone-like, "osteoid" tissue. A network of bony trabeculæ, with enclosed medullary spaces, gradually develops. During the second week the formation of the periosteal callus is so far advanced that it consists of a great number of osteoid and osteal trabeculæ—in other words, the two fragments are bound together by a young osteophyte made of wide-meshed bone tissue. At the

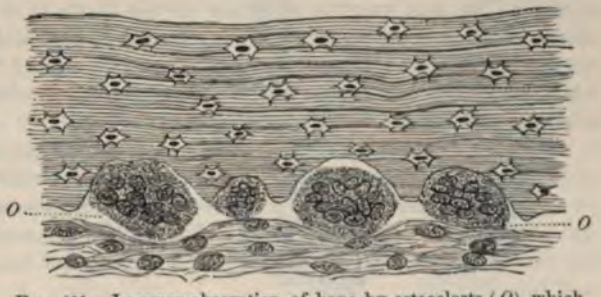


Fig. 401.—Lacunar absorption of bone by osteoclasts (*O*), which lie in Howship's lacunæ. × 250.

end of the third week (Fig. 399) the periosteal callus usually consists of fairly firm, spongy bone. Simultaneously with the formation of the periosteal callus the internal (myelogenic) callus develops in the medulla of the bone in the same way. On the inner surface of the cortex a trabecular system of osteoid tissue is formed, which gradually changes into true bone by the deposition of bone salts. The size of the medullary callus varies greatly, oftentimes filling the entire medullary cavity, while in other instances it may only develop to a slight extent. In the medullary callus also, particularly in the neighbourhood of the point of fracture, hyaline and fibrous cartilage is found, though not so constantly nor in so large amounts as in the periosteal callus. The so-called *intermediary* portion of the callus, which lies between the broken ends, develops, as we remarked before, principally from the periosteum.

FIG. 402.—Fracture healed with deformity (callus luxurians).

Retrogressive Metamorphosis of the Callus.—At the outset the callus is made up of spongy bone rich in marrow. This so-called provisional callus is then transformed into the permanent bone cicatrix by becoming more compact, decreasing in circumference, and becoming smooth on its surface. This involution of the callus may reach such completeness that the bone cicatrix is later on scarcely visible. If the medullary cavity was closed by the medullary callus it may again become free by absorption of bone. Wherever the bone substance formed in the ossification of the callus is not functionally necessary it is absorbed; while, on the other hand, apposition of bone substance takes place in those parts of the callus where they are necessary for the firmness of the bone cicatrix. In this way the structure of the bone at the point of fracture is regenerated as completely as possible and as the laws of statics demand. The regeneration of the medulla is brought about partly by the medullary cells and partly by proliferation of the leucocytes and nucleated red blood-corpuscles which increase rapidly by karyomitosis.

Billroth, Volkmann, Ollier, Bruns, and others have been instrumental in elucidating the subject of the formation of the callus, but the real founder of the experimental study of callus formation is Duhamel (1740), who showed by his classical investigations that the callus is not produced by any particular fluid of the body (Galen), but by a formation of bone from the periosteum and marrow.

The size and circumference of a callus varies greatly, according to the condition and position of the broken pieces, the location of the fracture, and the size of the bone. Constitutional conditions also exert an influence. The strongest callus, as a general thing, develops in fractures through the diaphysis of the long bones, which heal with displacement, especially if the fracture has been compound. Considerable disturbance of function may be produced by fractures like these which heal in a position of deformity with such a callus luxurians, as it is called (Fig. 402). The callus is generally slight in

flat bones like the scapula or those of the pelvis. After fractures of two parallel bones which lie next one another, as is the case in the forearm, it is possible for a synostosis of the two bones to occur. After fractures in the neighbourhood of joints the callus sometimes extends in the form of processes into the capsule of the joint, or bridges of callus develop, extending from the articular end of one bone to that of the other, and producing anchylosis of the joint. Occasionally true tumours (callus tumours) form from the callus at the point of fracture; these are sometimes benign osteomata, or enchondromata, and sometimes malignant periosteal or myelogenic sarcomata (Haberen). Lange observed the formation of multiple exostoses resulting from ossifying myositis which followed multiple fractures (Fig. 403). I removed successfully an osteochondroma the size of a fist from the horizontal and descending ramus of the os pubis which developed after a fracture.

Effect of Division of the Nerves upon the Callus Formation.—W. Kusmin, experimenting upon the posterior extremities of rabbits, has studied the effect on the callus of dividing the nerves, and he observed that after nerve division the callus is larger and stronger in all its stages than calluses formed without neurotomy, and the deposit of lime salts and ossification takes place at an earlier period and more extensively than is the case under normal conditions. According to Kapsamer, division of the sciatic nerve has no influence upon the callus formation.

Behaviour of Bone Splinters.—It is of special interest to note what happens to small fragments of bone. Those which remain attached to the periosteum or bone heal in place the most readily. But even completely detached and dead splinters of bone heal in place by bony union in the case of simple and of aseptic compound fractures, but are then gradually replaced by new-formed living bone tissue (see pages 608 and 609, Osteoplasty). If bone fragments do not become united to the rest of the bone, if they die and remain near the point of fracture, consolidation of the fracture may, in the case of large fragments, be very much delayed, or even entirely prevented, unless the dead portion of bone—the sequestrum, as it is called—is removed (see § 106, Necrosis of Bone).

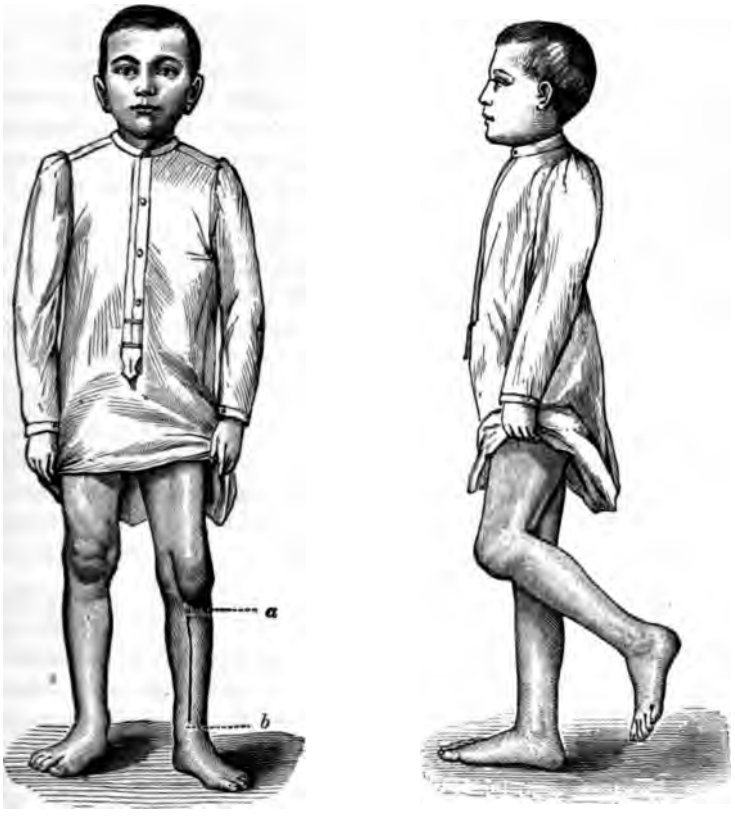
Fig. 403.—Multiple exostoses caused by ossifying myositis following multiple fractures (femur and pelvis).

Repair of Bone Defects—Osteoplasty.—The most important method of closing defects in bone is that in which living bone is employed with a broad nutrient bridge. Thus, in defects of the skull a flap is taken from the immediate vicinity of the defect consisting of skin periosteum and the outer

table of the skull, and this pedunculated flap is then turned into the defe where it unites by bony union in case the wound runs an aseptic course. is very necessary to avoid suppuration. In case of breaks in the continuity (long bones, pedunculated flaps of skin, periosteum, and bone are also used, o a flap consisting of bone and periosteum, with a nutrient bridge of periosteum is formed from one or both ends of the bone and turned into the defect or, finally, a flap of periosteum and bone which is connected with the soft parts may be pushed into the defect. In suitable cases the defect may be made good by a pedunculated piece of bone from an adjoining bone—e. g., by splitting the bone in question (metatarsal, metacarpal, forearm, leg). Finally, breaks in the continuity of the long bones may be repaired by cutting off the ends of the bone and uniting them by nails or sutures. Defects in the tibia may be repaired in this way after resecting a corresponding piece of bone from the fibula. Bergmann cured in this way a defect in the tibia of about eleven centimetres in length. In one case of defect in the tibia Hahn obtained a good result by chiselling through the fibula and uniting its lower end into the medullary cavity of the upper portion of the tibia. The same thing can be done in the case of the forearm.

In cases of large defects in the continuity of a bone, particularly a long bone, when it is impossible to use pedunculated flaps of periosteum and bone or of skin, periosteum, and bone in the way described above, and in cases where it is impracticable to unite the ends of the bone by sutures or nails, the defect may be filled in with fresh sterile pieces of human bone, a half to one centimetre in length and a quarter to half a centimetre in width or thickness, which are in a state of active growth, as in the case of the small pieces of healthy bone obtained during a sequestrotomy operation. Spongy bone from children, and any bone, in fact, obtained from bone operations on children, is very suitable for this purpose. The bone thus taken from the living subject is kept until used in 1 to 500 bichloride at a temperature of 40° C. (104° F.). In case it is not possible to obtain fresh human bone, one can make use of small pieces of bone from young growing animals, such as rabbits, or, what is simpler, small pieces of dead bone material from man or animal which contains calcium—e. g., bone charcoal (Barth). The wound in the skin is sutured over the material that is used for filling purposes, the upper and lower angles being left open. The extremity is immobilised, and suppuration must be avoided. Some authorities claim that small and completely separated pieces of living bone may heal in place again. Others, however, have shown that the living bone, like the dead bone material, acts merely as a temporary filling material; it heals in place only temporarily, acts as an irritant for the new production of bone, but is finally replaced by new bone tissue. The calcium in the pieces of bone is used for the formation of new bone tissue. If human osteoblasts are implanted at the same time, they aid directly in the formation of bone. The main point is to use bone material that contains calcium and is in an absorbable and sterile form (Barth). I healed a defect in the tibia, thirteen centimetres in length, resulting from complete necrosis of the shaft, by the implantation of numerous small pieces of bone taken from a ten-day-old rabbit (Fig. 404). About two thirds of the pieces of bone healed in place without suppuration and the other third came away in a necrotic state. In a second case I heale

defect in the tibia, nine centimetres in length, by the implantation of small ieces of human bone freshly chiselled. The pieces of bone, which before eing used had been placed for ten to fifteen minutes in 1 to 500 bichloride f mercury at a temperature of 40° C. (104° F.), all healed in without suppu- ition. In both cases the skin wound was closed, except at the upper and wer angles. The use of pieces of human bone and animal bone for filling defects has been attempted by various other surgeons. The disk of bone



. 404.—Complete necrosis of the shaft of the left tibia following acute suppurative osteomye- litis with extensive burrowing of pus in the vicinity of the knee. Restoration of necrotic shaft from *a* to *b* by transplantation of small pieces of bone from a ten-day-old rabbit freshly killed.

noved by the trephine has sometimes been made to heal in place again. cording to Barth, it is probably replaced gradually by newly formed bone, ile Wolff and others claim that the transplanted bone remains as such.

Finally, different kinds of sterile dead substances have been used as a ng material for bone defects or cavities. Dead bone, either decalcified or decalcified, has been used. Grekoff used with success bone charcoal. ber employed iodoform starch. The calcified material is only fitted for e cavities; the repair of a large defect in the continuity of a long bone

is hardly possible with uncalcified material. Bone defects in the skull have been closed by a celluloid plate. Gluck attempted to heal large pieces of ivory into defects in long bones, and even to make a sort of joint in place of a real joint. These attempts of Gluck have proved a failure. If a large dead piece of bone, such as ivory, is used for movements or for support, it does not heal in place permanently, and painful inflammatory (carious) processes take place in the adjacent living bone, so that the foreign body has to be removed, as Bergmann had to do in a case operated on by Gluck. In rare cases, however, large foreign bodies seem to have healed into defects in the long bones for a certain time at least. Giordano, for example, seems to have healed a piece of iron twenty-three centimetres long and ten to twelve millimetres thick into a defect in the tibia; it had a disk of ivory at its upper and lower end. Péan restored the upper half of the humerus by introducing an artificial appliance made of rubber and platiniridium. Unfortunately, subsequent reports on these cases have not been given, which are absolutely necessary.

The temporary introduction of pieces of ivory into the medullary cavity of long bones might come into consideration in the case of defects in the extremities for the purpose of stimulating the growth of bone. Bircher has used this method for securing the ends of the bone in compound fractures and pseudarthrosis. In the majority of cases the piece of ivory which had been implanted was removed after the bones had united.

As regards the filling in of bone cavities with hardening material, such as plaster of Paris, copper amalgam, dental gutta percha, and Richter's cement, it is at the present time impossible to give a definite opinion of its worth, but the method deserves further trial. It is not as yet suitable for defects in the continuity of bones, but in the case of bone cavities good results have occasionally been obtained. The chief difficulty consists in rendering a bone cavity perfectly germ free.

Repair of Fractures of Cartilage.—The process of repair in fractures of cartilage, such as the ossifying costal cartilages or laryngeal cartilages which are covered with perichondrium, is mainly carried on by the perichondrium, and a fibrous cartilage is formed, which then gradually ossifies. Regressive changes usually take place at the broken ends, and the cartilage undergoes fatty degeneration, but at a distance a little farther removed from the broken ends of the cartilage there occurs a vigorous proliferation of cartilage cells and a formation of new cartilage tissue (Tizzoni and others). In cases of interruption of continuity and loss of substance in the cartilage of joints which is not provided with perichondrium, a fibrous connective-tissue cicatrix ordinarily develops, which Tizzoni states is capable in time of changing into hyaline cartilage tissue. Portions of cartilage which have been completely broken off do not regain their attachments, and either become free bodies in the joint or are encapsulated by new connective tissue formed from the inner surface of the capsule.

The Time required for Fractures to Heal.—The time which is required for the callus formation to reach completion and render the affected bone again capable of performing its function, depends upon the size of the bone which is involved, the nature of the fracture, and

not infrequently also upon constitutional conditions. A simple subcutaneous fracture, as a general thing, heals more rapidly than a comminuted or a compound fracture with considerable injury to soft parts. In childhood, union takes place more rapidly than in adult life. The healing of a fracture may be prolonged by constitutional anomalies, such as the occurrence at the same time of severe acute constitutional infectious diseases, or by syphilis, scurvy, diabetes mellitus, and not infrequently by pregnancy. Gurlt has given the following periods as those required for the healing of simple subcutaneous fractures: A broken phalanx needs about two weeks, the metacarpus, metatarsus, and ribs three, the clavicle four, the forearm five, the humerus and fibula six, the neck of the humerus and the tibia seven, both bones of the leg eight, the femur ten, and the neck of the femur twelve weeks before consolidation is complete. The modern treatment of fractures has shortened the time of healing very materially. This has been brought about by the use of ambulatory splints, early massage with movements of the joints, and the not too prolonged use of immobilising splints.

Condition of the Soft Parts and Joints after Healing of a Fracture.—After consolidation of a fracture the full usefulness of the joints is not immediately restored, and the muscles very frequently have become atrophic as a result of their long inactivity. This muscular atrophy is probably in part of spinal origin, i. e., it is caused reflexly by irritation at the point of injury. Kiliani believes that it is due mainly to the toxic action of the absorbed extravasation of blood upon the centripetal nerve endings. From long-continued immobilisation or too tight dressings this atrophy of the muscles, particularly in anæmic individuals, may give rise to the ischæmic paralyses and contractures mentioned on page 569. Sometimes the functions of the muscles are disturbed by cicatricial shrinkage as a direct result of the injury, or by their insertion having been torn away, or by paralysis in consequence of a complicating injury to the nerves, or from compression of the nerves, for instance, by the callus. The skin very often exhibits slight disturbances of nutrition; it is dry and rough, and the epidermis comes off in scales. Very frequently there are varying degrees of œdema of the skin and subcutaneous soft parts. The rest which the healing of a fracture enjoins also has a deleterious effect upon the condition of the joints (Menzel, Reyher). In consequence of the shrinkage of the capsule of joints immobilised by the fracture dressing, the joints are more or less stiff after the splint is removed, and sometimes inflammatory effusions occur. Ordinarily, with the increasing use of the joint and under proper treatment (by massage and passive motion)

these disturbances very soon disappear. In other cases joint inflammations have their foundation in a direct injury of the joint, and under these circumstances it is possible for permanent joint disturbances, inflammation giving rise to deformity, anchylosis, etc., to occur (see Diseases of Joints).

Course of the Epiphyseal Separations.—The separations of the epiphyses run essentially the same course as fractures of the bone. We still lack precise anatomical knowledge upon the phenomena of their healing. Great interest attaches to the question of how much disturbance after epiphyseal separations has been observed in the growth of the affected bone on account of ossification of the epiphyseal cartilage. Unfortunately, only a few observations have been recorded on this subject. Bruns's statistics show that a consequent arrest of development only occurs in rare and exceptional instances to any marked degree. Vogt has recorded observations of this kind. In Fig. 405 is represented a shortening of the humerus amounting to twelve and one half centimetres in a thirty-year-old woman which was probably the result of a traumatic separation of the epiphysis sustained in childhood, with subsequent anchylosis of the shoulder joint. Shortening develops especially when the diaphysis and epiphysis are driven into one another and heal together in this position, or when, in consequence of simultaneous injury to the adjacent layer of epiphyseal bone, a growth of bone makes its way through the epiphyseal cartilage into the diaphysis and unites epiphysis and shaft so that the further growth is arrested (Nové-Josserand).

Fig. 405.—Impeded growth of the right humerus, probably resulting from a traumatic separation of the epiphysis (Bryant).

Disturbances during the Healing of Fractures.—The most important disturbances which may arise while a fracture is healing are briefly as follows:

1. *Shock.* See § 63.
2. *Delirium Tremens.* See § 64.
3. *Infectious Diseases of Wounds.* See §§ 66–75.—These are particularly liable to occur in the case of compound fractures which have not been treated antiseptically.

4. *Gangrene.*—See § 100.—This may be caused by severe injury of the soft parts, by injury to the larger vessels, by pressure of the fragments upon the main artery, by improper treatment, such as too tight dressings, etc.

5. *Necrosis of the Ends of the Fragments.*—This is especially apt to occur in compound fractures when the broken ends lie in the wound stripped of their periosteum, or when they are badly crushed or splintered into several fragments, or when the periosteum and medulla are to a great extent destroyed by suppuration and sloughing. The dead bone—or sequestrum, as it is called—is then separated from the living bone by a demarcating suppuration (see § 106, Necrosis of Bone).

6. *Fat Emboli.*—Probably in every fracture, as a result of the laceration of the bone marrow and subcutaneous adipose tissue, fluid fat gains access to the blood and lymph vessels which are opened at the point of fracture. Wherever the lumen of the vessels is too small for the passage of the fat drops circulating in the blood at this point, these drops lodge and occlude the vessel. Fat emboli of this kind following fractures are observed particularly in the pulmonary capillaries, and they also frequently occur in the smallest vessels of the brain, kidneys, liver, intestinal villi, etc. As long as the fat emboli are scattered and not extensive their occurrence is entirely unimportant; the fat produces no symptoms worth mentioning of either a local or constitutional nature, beyond causing a temporary occlusion of the lumen of the vessel in question. But sometimes the fat emboli in the lungs or brain are so numerous and so extensive as to cause death, not only in those weakened by age, but now and then in those who are in the prime of life. Death is due to a pronounced accumulation of fat in the capillaries of either the lungs or the brain. Scriba has performed experiments to determine the manner in which fat emboli act, and he maintains that death is mainly the result of their lodgment in the brain. As a rule, death occurs about three to four days after the fracture, and in such cases there is a continual accumulation of fat, during several days, in the capillaries of the lungs and brain, which finally causes a more or less sudden functional incapacity of these organs. It is comparatively seldom that death is the result of fat emboli alone; there are generally other complications.

7. *Embolism of the Pulmonary Artery following Thrombosis of the Larger Veins at the Region of Fracture.*—This serious complication may occur particularly after thrombosis of the deep veins in fractures of the lower extremity. The thrombus in the vein may break loose either while the patient is lying quietly in bed, or because of some

movement of the body, from massage, or from a change of the dres ing, and death may follow within a few seconds from embolism of th pulmonary artery. König observed death from embolism of the pul monary artery on the eighteenth day after a subcutaneous fracture c the leg in a strong man thirty years of age. When the patient wa laid upon the operating table preparatory to changing the dressing he was suddenly seized with cramps and opisthotonus, the pupi became dilated, and he died in a few moments. The autopsy reveale a large clot lodged in the pulmonary artery, and it was only with diff culty that the point was found in the anterior tibial vein where th thrombus had originated.

8. *Hæmorrhage.*—In compound and subcutaneous fractures hæmo rhage may occur as a result of the violence which has been brougl to bear upon the part, or it may be produced by pointed fragment splinters of bone, etc. (see §§ 87–89).

9. *Constitutional anomalies* play an important part in respect t the prognosis in the case of any fracture. A fracture sustained by very old person and entailing a long confinement in bed is a serio accident, for the reason that life may readily become endangered b hypostatic pneumonia.

10. *Delay in the formation of the callus* is particularly apt to occu when constitutional anomalies exist, or in acute and chronic infectio diseases (typhoid fever, syphilis, scurvy), in diabetes mellitus, in disease of the peripheral nerve and central nervous system such as progressive paraly sis, or during pregnancy, etc

Fig. 406.—Pseudarthrosis of the humerus twelve years old in a fifty-three-year-old man.

11. *Pseudarthrosis.*—I bony union does not tak place between the frag ments, the resulting condi tion is called a pseudarthro sis—i. e., a false joint (see Fig. 406). In a case of pseudarthrosis, the frag ments are either entirely free from connection wit one another, or they are joined together by a connective-tissue or ca tilaginous intervening substance of varying strength. In rare instanc a kind of true joint is observed at the point of fracture—i. e., the en of the fragments are covered with a layer of hyaline cartilage, and shallow cavity is hollowed out of one fragment, while the other

rounded to fit it; the periosteum and neighbouring connective tissue surrounds and encloses the broken pieces in the form of a capsule, and in some cases there will be found in the joint-like cavity a fluid which resembles synovia. In pseudarthroses such as this, even synovial villi and loose bodies have been found, the latter sometimes in great numbers.

Occurrence of Pseudarthrosis.—In general, pseudarthrosis is not of common occurrence. Karmilow states that a pseudarthrosis takes place once in about three hundred or four hundred fractures. The pseudarthroses following fracture of the neck of the femur and fracture of the patella are the most frequent. Bruns's statistics seem to show that childhood and old age predispose less to pseudarthrosis than middle life. In fact, pseudarthroses are very rare in children, particularly in the bones of the forearm, but they are more common in the humerus and tibia.

Causes of Pseudarthrosis.—The causes of pseudarthrosis are usually local in their nature, being principally those which prevent exact coaptation of the wounded bone surfaces. A pseudarthrosis may result, for example, from a diastasis of the fragments, such as often occurs after transverse fracture of the patella or after loss of a large portion of a bone, owing to its becoming extensively crushed; or the affection may result from displacement of the fragments, or from interposition of muscles, tendons, fascia, foreign bodies (bullets), pieces of dead bone, etc., between the fractured surfaces. In other cases—for instance, after intracapsular fractures of the neck of the femur, or intracapsular fractures of the neck of the humerus—the pseudarthrosis is caused by the insufficient nourishment of one of the fragments. Pseudarthrosis may also originate in consequence of insufficient coaptation of the fractured surfaces due to defective dressings, particularly if the fracture is oblique; under these conditions the fragments are permitted to move and become separated. An influence is sometimes exerted in this direction by a paralysis which may exist at the time of the fracture, or by too little inflammatory reaction in consequence, for example, of the wound healing aseptically in the case of compound fractures. Constitutional disturbances, especially the general weak condition which follows severe febrile diseases, loss of blood, prolonged lactation, pregnancy, etc., have in rare instances given rise to pseudarthroses. Under these circumstances it has also happened that an already ossified callus has softened and been completely absorbed. Whether injuries and diseases of the central nervous system and the peripheral nerves really predispose to pseudarthrosis, as has been maintained, seems to me doubtful.

The degree of functional disturbance resulting from a pseudarthrosis depends mainly upon the location of the latter, the function of the bone which is involved, and especially upon the amount of motion possessed by the false joint. In a pronounced pseudarthrosis of a long bone, like the femur or humerus, the affected portion of the limb or the entire extremity is quite useless, unless some supporting apparatus is worn.

Diagnosis of Fractures.—The diagnosis of fractures is made from the above-described symptoms. In order to make out the latter, a systematic and careful examination of the injury should be undertaken. This examination consists: 1. In a thorough inspection of the injured portion of the body, noting, for example, changes in its shape and disturbances of function. 2. In palpation of the place where the fracture is presumed to be, combined with passive motion. 3. In an exact measurement of the length of the injured bone, or, rather, the extremity, to determine the existence and amount of shortening. Simple inspection will often be sufficient for the immediate recognition of a fracture. Entirely apart from the crepitus and abnormal mobility, the characteristic linear pain obtained by palpation of the line of fracture will frequently betray the existence of a fracture. In order to palpate the line of fracture more readily, the extravasation at the point of fracture should, when practicable, be removed, or at least diminished in amount, by gentle massage. The corresponding sound portion of the body should always be compared with the injured part, with a view to determining how far the normal position of the constituent parts has been altered by the injury. Not infrequently we have to make the examination during narcosis to find out the exact nature of the fracture, especially when it is compound. In all cases where the diagnosis of fracture is doubtful the injury should always be treated, for the first, at least, according to the rules which govern the treatment of fractures.

Percussion and Auscultation of Bones.—Lücke and Hueter have recommended percussion and auscultation of the bone as an aid in the diagnosis of fractures, particularly when it is desired to determine the presence of fissures in the skull, which can be recognised by the pain the patient feels during the percussion. If soft parts are interposed between the ends of the fragments, Hueter states that auscultation (osteophony) will show a diminution or complete cessation of the conduction of sound.

As regards the use of the X-rays in the diagnosis of injuries and diseases of bone, see § 124.

The Prognosis of Fractures.—The prognosis of subcutaneous fractures without much injury of the surrounding soft parts is, in general, favourable. Transverse fractures heal more rapidly and are less apt to cause lasting deformity than oblique fractures. The location of the fracture is an exceedingly important matter as regards the prognosis. The latter is more favourable in fractures of the extremities than in those of the bones of the skull, trunk, and pelvis, in which the concomitant injuries of neighbouring organs of vital importance, such as the brain, spinal cord, lungs, heart, bladder, etc., may readily give rise to very serious disturbances or death. In other cases

injury to a neighbouring large vessel may cause fatal hæmorrhage, or, when the middle meningeal artery is wounded, cerebral compression, with possibly fatal results.

Fractures of the lower extremities in old people, necessitating their confinement to bed for weeks, are always to be looked upon as severe injuries. As a result of the long-continued dorsal decubitus, general disturbances of nutrition, bronchitis, and hypostatic processes in the lungs readily develop, which very often terminate fatally. This fact is of therapeutic importance, as it teaches us in proper cases to permit patients with fracture of the neck of the femur, for example, to get about in ambulatory splints as soon as possible.

The prognosis of fractures involving the articular ends of bones of the extremities is very frequently unfavourable, particularly as regards restoration of the function of the joint.

The character of the fracture exerts a very important influence upon the prognosis as regards the preservation of the patient's life and the saving of the injured limb, as well as its complete *restitutio ad integrum*. Compound fractures, in particular, are always to be looked upon as severe injuries, and ones which threaten both the limb and life itself, but thanks to Lister's antiseptic method of treating wounds, we are no longer powerless to combat infectious-wound diseases. In the pre-antiseptic times the mortality of compound fractures amounted to thirty-five to forty per cent., and in especially infected hospitals even to sixty to seventy per cent. and more. Three quarters of the fatal cases were due to septicæmia and pyæmia. At present the mortality of compound fractures, when timely and proper antiseptic treatment is bestowed upon the wound, is extremely small, for the reason that we have learned to prevent infectious-wound diseases. From this it is plain that the prognosis of a compound fracture is, in general, more favourable the earlier it is placed under the protection of antiseptic treatment.

Frequently it may be impossible to preserve the broken limb, so that either immediately after the injury, or later, amputation of the extremity must be undertaken.

The extent to which the prognosis of any fracture, subcutaneous as well as compound, may be affected by various accidental circumstances, has been discussed on pages 612–614.

Treatment of Fractures.—The first aid to the person who has just sustained a fracture often falls to the share of the laity who happen to be present at the accident. Unfortunately, their assistance frequently does more harm than good. In fractures of the upper extremity the patient usually instinctively places the broken limb in a proper position. But the conditions are entirely different in all fractures of the pelvis, vertebræ, and lower extremity, in consequence of which the injured person is unable to walk. Under these conditions the patient must be lifted cautiously after securely supporting the point of fracture. If an individual who has received an injury of this kind has to be transported to his home or to a hospital, the fractured part should be placed in the most secure position possible, a suitable temporary dressing applied to

prevent unnecessary pain and displacement of the ends of the fragments, as well as serious injuries, such as perforation of the skin and severe wounds of the soft parts, particularly of the vessels, with dangerous hæmorrhage, etc. Great care should be used in removing the patient's clothes, portions of the latter—his boots, etc.—when necessary, being slit up with a knife or scissors. The technique of applying an impromptu dressing, the various splints, the arrangement of the bed, the position of the patient, etc., are described in §§ 52–55.

The treatment of the fracture itself consists, in the case of a simple fracture, in correcting the deformity as soon as possible—i. e., in reposition or reduction of the fragments, and in retention or fixation of the broken pieces after they have been placed in apposition by a suitable retentive dressing until bony union is complete.

Reduction of the Fragments.—Reduction or return of the displaced fragments into their normal position is usually brought about by extension (traction) and counter-extension in the longitudinal axis of the broken bone. The extension and counter-extension of the broken limb are usually cautiously performed by two assistants, while the surgeon grasps the point of fracture and brings the fragments into their normal position (coaptation). Manual reposition or reduction will almost always be sufficient. If great force has to be used, or if the pain is intense, an anæsthetic may have to be employed. Extension apparatus, such as the pulley or Schneider-Mennel's frame, which were at one time very much used, have become antiquated. The reduction of many fractures, such as those of the bones of the face or through the condyles in the immediate neighbourhood of a joint, etc., can be accomplished simply by direct manipulation, without extension and counter-extension.

Obstacles to Reduction.—Occasionally various obstacles stand in the way of the successful reduction of a fracture. These include the interposition of splinters of bone or of soft parts between the fragments, impaction of the broken ends in fractures of the articular extremities of bones, and the impossibility of bringing sufficient power to bear upon the fragments. Impaction of the broken ends, such as may occur in fractures of the neck of the femur, should be let alone, for the reason that the impaction favours consolidation of the fracture.

Application of Retentive Dressings.—There are a great number of splints and dressings described in §§ 53–55 for holding the fragments in their normal position after they have been brought into apposition. The ordinary dressing for a fracture is the rapidly hardening retentive appliance made of plaster of Paris (page 217). Extension apparatus are generally used for fractures of the thigh, and can also be employed

for the upper extremity (see § 55, page 230), while special splints are recommended for many fractures, such as those of the lower end of the radius. The hardening retentive dressings should be applied as soon as possible, and it very often happens that subcutaneous fractures will heal under a single dressing. If the swelling at the point of fracture is considerable, ice can be applied to the surface for several days with advantage, and then, after the inflammatory swelling has been reduced, the limb can be placed in the hardening dressing. Even though the swelling is marked the plaster-of-Paris dressing can be immediately applied, if the parts are first carefully padded with cotton. In such cases the hardening dressing has an antiphlogistic effect from its gentle and even pressure—i. e., it prevents an increase in the swelling. After a certain length of time this dressing becomes loose and does not sufficiently immobilise the point of fracture, and hence it must be taken off and replaced by a new one. The closed plaster dressing should be replaced as soon as possible by one that can be removed—e. g., one that is slit up in front and provided with laces (plaster of Paris, plaster and glue, or plaster and water glass, etc.), or by a wooden splint, in order that the fractured limb may be massaged daily and the joints moved. In putting on the hardening dressing great care must be taken not to apply it too tightly. Subsequently the fingers and toes should be carefully watched, and if they swell or become bluish-red or œdematous, if pain or a feeling of numbness occur, the bandage has been applied too tightly and must be immediately removed. Every plaster-of-Paris dressing, whenever it is possible, should be again carefully inspected some hours afterwards to determine whether it has not been applied too tightly. Incurable ischæmic muscular contractures may readily develop within a few hours after the application of a plaster-of-Paris dressing which is too tight (see page 569), and for these the attending physician can be held legally responsible.

A warning should be given against the too prolonged use of retentive dressings and the rest in bed which this entails, because of the bad effect produced upon the general health, the atrophy of the muscles, the enforced disuse of the joints, etc. On account of these serious possibilities, and particularly on account of the danger of hypostasis, old people with fractures of the lower extremities must often be allowed to leave their bed and go about on crutches with a suitable splint, and with a raised sole on the shoe of the sound leg. Recently successful results have been obtained by allowing all patients with fractures to walk about with suitable splint dressings, and by avoiding, for the above-mentioned reasons, the treatment with dressings which require a long confinement to bed. The results are favourable, the time required for

union is shortened, and the injurious effect of confinement in bed upon the general health is prevented. Ambulatory splints are also very useful in military surgery. In cases where it is not advisable to employ ambulatory splints at once, the patient remains in bed for four to eight days, using ordinary splints or, in case of the femur, an extension apparatus. He is then allowed to go about in specially constructed portative splints, such as a Thomas hip splint (Figs. 407 and 408). Kraus, Bardeleben, and others apply a closely fitting plaster splint to the extremity, which is bandaged with muslin or smeared with fat. In case of fractures of the femur iron bands are included in the plaster splint, and at the upper end of the latter a ring of plaster is applied as a support for the tuberosity of the ischium. My ambulatory splints are very simple.

FIG. 407.—Immobilisation of the hip in disease of the right hip.

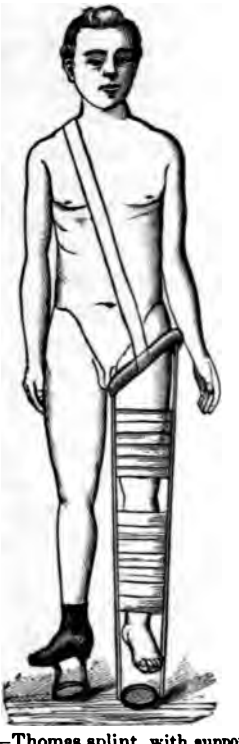


FIG. 408.—Thomas splint, with support at the tuberosity of the ischium and raised sole under the sound foot, for diseases of the hip and knee.

I either use plaster or plaster and water-glass splints, which are removable—i. e., they are slit up in front and can be laced—or else closed plaster or plaster and water-glass splints, to which I fasten, either at once or the next day, an iron stirrup for walking (Fig. 409). The stirrup is some

listance from the sole of the foot, and if a raised sole is used on the other foot the patient can walk about very comfortably. This stirrup also acts to extend the leg (Fig. 410). In injuries and diseases of the hip the pelvis is included in the ambulatory splint (Fig. 411).

Treatment of Subcutaneous Fractures involving a Joint.—In subcutaneous fractures involving a joint special care must be taken to prevent the development of anchylosis or a partially stiff joint (contractures). This is best accomplished by the use of suitable splints or a plaster-of-Paris dressing, which should be frequently changed—every five to eight days, for example—and reapplied after altering the position of the joint. Massage and passive motion may be combined with this—for example, at every change of dressing. Extension appliances are very

Fig. 409.—"Stirrup" for ambulatory splint.

Fig. 410.—Ambulatory splint with iron stirrup.

Fig. 411.—Ambulatory splint of plaster with iron stirrup for injuries and diseases of the hip and upper end of the femur.

useful, and may be employed also, as Bardenheuer has recently recommended, for fractures of the upper extremity which involve joints. If it is difficult to maintain the fragments in position after they have been reduced, they may be fastened together by aseptic steel nails or pins (see page 117).

Treatment of Traumatic Separation of the Epiphysis.—For securing bony union after traumatic separations of the epiphyses, the fragments should be directly united by long aseptic steel nails or pins (Trendelenburg, Bruns, etc.). Helferich has recommended long steel pins attached to a removable handle, by which they can be slowly screwed into a bone; they can be used for both subcutaneous and compound epiphyseal separations.

Direct Fixation of the Fragments in Simple and Compound Fractures by Suturing, Nailing, etc.—In all subcutaneous or compound fractures, where it is difficult to maintain the fragments in proper position, the wounded bone surfaces can be held in contact by sutures of silver wire, or, better, of aluminium-bronze wire, by nails, ivory pegs, steel pins, Gussenbauer's or Parkhill's clamps, or by bone rings (Senn), as described on page 118 (Union of Bone Surfaces). In this category belong

Malgaigne's hooks for fracture of the patella and Malgaigne's pin for fracture of the tibia—instruments which are scarcely ever used at present. If nails are to be used to secure fixation of the bones, long four-cornered steel ones should be employed. These are polished, boiled for fifteen minutes in a one-per-cent. soda solution, heated red-hot, and placed in a ten-per-cent. solution of carbolic acid in glycerine, after which they are perfectly sterile. After the bones have been nailed together they are securely immobilised. The wounds in compound fractures are not sutured, but packed with sterilised gauze. The nails are removed about the beginning of the fourth week.

The Treatment of Compound Fractures.—The treatment of compound fractures has been totally changed by the antiseptic method of treating wounds, and the results which we now obtain are very satisfactory. Typical cases of compound fracture which run an aseptic course heal without pain and without fever; the discharge from the wound is slight, and we are certain of being able to prevent suppuration. The splints used are in general the same as in simple fractures, particularly fenestrated plaster splints, and the ambulatory splints described on page 620.

The technique of the antiseptic treatment of the wound varies with the kind of case. For this reason we distinguish three classes of cases: 1. The perfectly fresh fractures in which the wound is the result of a perforation of the skin by a fragment. 2. The ordinary severe cases of compound fracture. 3. The compound fractures which are not recent and have already become infected.

1. **Treatment of Fresh Fractures with Transfixion of the Skin by a Fragment.**—The antiseptic management of a perfectly fresh fracture complicated with a perforation of the skin by a fragment is as follows: We will suppose that we have to deal with a fracture accompanied by only a small, still bleeding cutaneous wound, similar to a punctured wound; that the case comes under observation immediately or within a few hours after the reception of the injury; that there is no large extravasation of blood present; that the bone is simply broken, and not splintered; and that no infection has occurred. In such cases enlargement of the wound and drainage can be omitted. After disinfection of the wound and surrounding parts, as described in § 6 and § 32, the wound is covered with an aseptic dressing, such as sterilised gauze, folded together into several layers, and cotton, wool, or pads filled with moss. Should the wound have become closed by a dried blood-clot and no indications of infection be present, this scab can be left undisturbed and the fracture allowed to heal under it. A plaster-of-Paris dressing can then be immediately applied over the aseptic dressing.

This aseptic plaster-of-Paris occlusive dressing is left in place, if no fever or pain in the wound occurs, for two or three weeks longer, until the wound has healed, and is then, if necessary, replaced by a simple plaster-of-Paris dressing until complete consolidation of the fracture has taken place. This aseptic plaster-of-Paris occlusive dressing has been recently very much employed for fresh compound fractures with small wounds, and also in the treatment following osteotomies of the rhachitic extremities of children. Bergmann, Reyher, and others obtained brilliant results in the Turko-Russian War with this same form of dressing, even in such injuries as gunshot wounds of the knee. The method is not suitable for severe compound fractures with extensive wounds of the soft parts, nor for cases which are not perfectly fresh when they come for treatment.

The opinions of surgeons still differ as to whether the aseptic occlusion carried out in the manner above described should likewise be used for fresh comminuted fractures with a small cutaneous wound, or whether the wound should be enlarged and the splinters extracted. At all events, the brilliant results obtained by Bergmann and Reyher in the Turko-Russian War show that the primary extraction of the fragments, formerly so much insisted upon in comminuted fractures, is not always necessary; that the above-described simple aseptic occlusion, without enlarging the wound and without extraction of the fragments, gives even here excellent results; and that the splinters, though very numerous, are capable of healing up completely in the wound, provided the latter runs an aseptic course. If the wound suppurates, the splinters of bone will then not heal in and will have to be removed.

2. **The Antiseptic Management of Severe Compound Fractures,** with extensive injury to the soft parts, likewise consists in a thorough disinfection of every portion of the wounded surface and of the surrounding parts to a considerable distance from the wound. If the opening is not large enough to permit of careful examination or disinfection of the entire wound cavity, it should be enlarged with the knife, using for the extremities an Esmarch bandage. The point of fracture is inspected, and the entire cavity of the wound is energetically irrigated with a one-tenth-per-cent. solution of bichloride of mercury, crushed shreds of tissue are cut off with the scissors and forceps, the hæmorrhage carefully arrested, foreign bodies, bullets, etc., are removed, and long, deep pockets under the skin or deeper parts are slit open. If necessary, the fragments may be drawn out of the wound with sharp hooks or bone forceps, to render it possible to systematically examine and disinfect them and the soft parts lying behind them. Counter-openings are made for the admission of short, large-sized drainage tubes

to the most deeply lying parts, and every niche, every recess in the wound, and every pocket, should be carefully drained or slit open. The deep drains should always extend to the cleft in the bone, but should not lie between the fragments. Packing the wound with iodoform gauze or sterilised mull supplies excellent drainage. If splinters are present, all those which are entirely loose and dead should be removed, while those, on the other hand, which are still alive and attached to the periosteum should be retained, and, if displaced, returned to their normal position. Projecting points on the fragments which interfere with reduction should be removed with the bone forceps or saw. If it is difficult to maintain the fragments in position after their reduction, they may be secured in their normal situation by sutures through the ends of the bone, or by nailing them together aseptically (see page 621).

After the wound, with all its recesses, has been very carefully disinfected and drained, we proceed to insert the sutures, provided the case is one suited for primary union. I believe it is wiser not to suture wounds of this kind, but to leave them open and pack them with iodoform gauze and sterilised mull, over which is placed an antiseptic protective dressing.

Resection of the Broken Ends.—Formerly, in the case of compound comminuted fractures of the long hollow bones, the splintered ends of the bone were frequently removed (so-called resection in continuity). This primary resection immediately after the injury is only applicable to the most severe cases. If, during the subsequent course of compound comminuted fractures, necrosis of the broken ends takes place, then secondary resection of the fragments is indicated to obtain more rapid healing.

Treatment of Compound Fractures of Joints.—If we have to deal with a compound fracture of a joint, we proceed according to the same principles—i. e., the joint is exposed by a sufficiently long incision, carefully disinfected, and drainage provided for. When necessary, we also remove any crushed fragments of bone, extract the free splinters, or, in the severest cases, perform total resection of the articular ends of the bones. Speaking generally, resection in compound fractures of a joint is governed by the following principles (see § 40): Primary resection is indicated in fresh, non-infected, extensively comminuted fractures of the articular ends of the bones, accompanied by great injury to the soft parts. Compound fractures involving a joint with only a small cutaneous wound, after careful disinfection of the latter, should be treated at first as though the fracture were subcutaneous. If the attempt fails, and inflammation or suppuration of the joint with fever comes on, then

arthrotomy should be performed—i. e., the joint is opened freely, the fracture exposed, carefully disinfected, and drained. Not infrequently, under these conditions, fixation of the fragments by sutures or nails renders excellent service. Whether a typical resection of the broken articular extremities should be performed depends upon the character and severity of the injury to the bone and the extent of suppuration or infection. At all events, resection is indicated when fever and local inflammation continue after arthrotomy and drainage of the joint, and when there is a probability of a severe infection of the wound of the bone having taken place.

Subsequent Treatment of Compound Fractures.—The rest of the treatment of compound fractures depends upon their subsequent behaviour. In the most favourable cases, running a course free from fever, the first dressing is left in place six to eight to ten to fourteen days and then changed, and at the same time any drains, sutures, or tampons are removed. If, on the other hand, fever should occur, or the patient complain of pain in the wound, the dressing should be immediately changed and the wound and parts surrounding it carefully examined for the presence of retained discharges, which should be immediately let out by an incision. The granulating wound should also be treated strictly according to antiseptic principles, and a closed or fenestrated plaster splint, or one of the modifications given under § 54, applied until the wound has become covered with skin. We cover large granulating surfaces with skin by Thiersch's method of skin grafting. When the wound has healed, a closed plaster splint is applied, if necessary, until consolidation of the fracture is complete.

3. **Treatment of Fractures which are not Fresh and have become Septic.**—We count all cases as not "fresh" which come under observation twenty-four to forty-eight hours after the injury, with already existing local inflammatory changes in the wound. Of course, the character of these cases varies greatly, according to the severity and nature of the reaction which is present in the wound. If the reaction in the wound is slight, an aseptic course of repair may not infrequently be obtained by energetically disinfecting, enlarging, and draining the wound and then applying an antiseptic occlusive dressing. Packing the cavity of the wound with iodoform gauze or sterilised mull, and omitting all sutures, is a procedure particularly applicable for such cases.

In other instances, again, the reaction in the wound will have already become very marked. There is pronounced decomposition and putrefaction of the discharges, and the crushed soft parts and cellular tissue are gangrenous, and saturated with the products of decom-

position. The suppuration and putrefaction which are present are no longer limited to the wound, but have begun to spread progressively. Not infrequently there is such a large accumulation of putrefactive gases that a pronounced gaseous infiltration (emphysema) takes place. Even in such unfavourable cases of pronounced sepsis a vigorous disinfection of all the septic tissues should be undertaken and incisions made in great numbers. We, of course, avoid applying the ordinary closed protective dressings which exert pressure, and content ourselves with energetic disinfection of the wound, covering it with sterilised gauze or iodoform gauze, or employing permanent antiseptic irrigation (see page 181). As long as the treatment lasts it is exceedingly important to keep the extremity in an elevated position and the fragments as securely immobilised as possible. When the wound has become aseptic and is granulating, we cover it with iodoform gauze and cotton and immobilise the fragments by a suitable splint, or by a fenestrated or interrupted plaster-of-Paris dressing. The treatment of compound fractures which have become infected demands much patience and care, and, above all, experience. It is very important to note the behaviour of the temperature by means of the constant use of the thermometer, and to recognise any retention of discharges at the earliest possible moment and to let them out by incisions.

Indications for Amputation and Disarticulation.—In what cases of compound fracture should amputation or disarticulation of the injured limb be performed? Immediate amputation or disarticulation of the injured limb directly after the reception of the injury, or within the first twenty-four to forty-eight hours, before the reaction in the wound sets in, is only indicated in cases of very severe crushing of the bone with extensive injury to the soft parts (primary amputation). With the aid of the antiseptic method of treating wounds we are enabled to carry out conservative treatment successfully in cases where formerly preservation of the injured limb would have been impossible. The opening of a large joint or injury of large arteries and nerves do not in themselves indicate primary amputation, though it should be immediately performed if the soft parts, muscles, vessels, and nerves are so extensively lacerated and crushed that preservation of the limb is impossible or gangrene is sure to follow. The decision as to whether amputation should be immediately performed or not is not always easy. After having determined upon amputation, we perform it through sound tissues which have not been crushed, and take the greatest care to avoid fashioning the flaps which are to cover the amputation wound from the contused portions of skin or those portions that have been torn loose from the underlying parts.

Amputation is also indicated in the case of many infected compound fractures when the local wound infection, the suppuration, putrefaction, etc., have become so extensive as to render preservation of the limb impossible, or when severe manifestations of general septic infection make their appearance. In such cases we amputate—in other words, we remove the

source of infection in order to save the life of the patient. Delay in such cases is dangerous, and the sooner amputation is performed in the presence of high, septic fever, the better is the prospect of recovery. In the later stages of compound fractures amputation is indicated, especially when there is extensive suppurative inflammation of the medulla of the bone or of the joints, or when the patient is in danger of exhaustion from severe suppuration, etc. Briefly speaking, we amputate when the condition of the extremity is such that healing cannot be expected from conservative treatment.

After-treatment of Fractures.—The after-treatment is directed principally towards the disturbances in nutrition which occur in the soft parts, particularly the skin, muscles, and joints. Very often no special after-treatment is necessary when consolidation of the fracture is completed. Massage, diligent exercise of the muscles, and active and passive motion of the joints will usually soon remedy the muscular weakness and the stiffness of the joints, and the sooner these measures are adopted the better. A warning should be given against the too protracted use of retentive dressings for fractures, on account of the atrophy of the muscles and the disturbances in the functions of the joints which they cause. In the case of old people particularly it is often necessary to give up the confinement to bed because of the threatening hypostasis or disturbance of the general health, and to permit them to move about, even with fractures of the lower extremity, in ambulatory splints (see pages 620 and 621). In proper cases, such as in fractures of the radius with the ulna intact, or of the fibula with the tibia intact, massage can be done at a very early period—within the first or second week, for instance—and a more rapid recovery will thus be obtained. Of course, the above-mentioned fractures must be immobilised a long enough time—two to three weeks at least—by proper splints. Baths and rubbing with alcohol are also of use. If there is much œdema, particularly, for example, in the case of the lower extremity, the latter should be enveloped in a tight flannel bandage, or retentive dressings which can be readily removed should be applied (Figs. 225, 232). If a long time has elapsed since consolidation of a fracture of an extremity, and if the stiffness of the joints and atrophy of the muscles, owing to lack of energy on the part of the patient or physician, have become very pronounced, it is all the more difficult to restore the normal function. In such cases it is sometimes best to repeatedly anæsthetise the patients for the purpose of moving the joints and performing vigorous massage. It is in just these cases that massage not infrequently yields most brilliant results. In these old cases, where motion is impaired and there are contractures and muscular atrophy, methodical exercises by means of the mechanical appliances in the orthopædic institutes are exceedingly valuable. If we

have to deal with ischæmic contractures and paralyses, they should be treated according to the rules mentioned on page 570.

Treatment of the Complications.—The treatment of the above-mentioned complications is described in previous paragraphs—shock in § 63, delirium tremens in § 64, infectious diseases of wounds in §§ 66–75, and gangrene in § 100, etc.

Treatment of Delayed Callus Formation and Pseudarthrosis.—For these conditions the following methods are particularly valuable: 1. Rubbing together the ends of the bones (Celsus), according to Karmilow, was successful only forty times in four hundred and thirty cases. In this method, which is suited more for cases with delayed callus formation, the fragments are rubbed together daily until a sufficient local reaction has set in and the point of fracture is tender on pressure. A plaster-of-Paris dressing is then applied. Patients with fracture of the lower extremity can be allowed to move about in a retentive dressing for the purpose of maintaining an inflammatory irritation at the point of fracture. These ambulatory splints often bring about a prompt result. 2. Artificial increase of bone formation by the production of a venous hyperæmia at the point of fracture by tying off the extremity on the proximal side of the fracture with a rubber tourniquet drawn moderately tight. In order that the hyperæmia may be localised at the point of fracture the extremity above and below it can be enveloped in a bandage (Dumreicher, Helferich, etc.). The procedure can be combined with the application of a plaster or other kind of splint, and it is here also a good plan to permit patients with fracture of the lower extremity to move about in a proper dressing. 3. Le Fort has successfully employed electrolysis—i. e., two platinum needles connected with a constant battery are stuck into the false joint. The needle fastened to the positive pole is kept in one place, while that fastened to the negative pole is introduced repeatedly at several different points. 4. The employment of various other means of irritation has been abandoned (irritation of the skin, subcutaneous injections of irritating chemical liquids, etc.). Nevertheless, Mikulicz has used oil of turpentine with excellent results. After making a longitudinal incision through the soft parts and periosteum, the latter is freed from almost the entire circumference of the bone with the raspatory to a distance of about ten centimetres from the point of fracture, and gauze saturated with oil of turpentine is placed between the bone and periosteum and changed every three to five days until the wound has healed. As yet, Bergmann has seen no case of pseudarthrosis cured by the oil-of-turpentine treatment. 5. Irritation of the ends of the bones by driving ivory pegs into them (Dieffenbach) is performed in the following

manner: After the soft parts above and below the point of fracture have been divided with the knife, holes are bored in the bone with a drill, and one or two ivory pegs, according to the size of the bone, are driven into each fragment. The extremity is then encased in a plaster dressing, which may be fenestrated or not. The ivory pegs are allowed to remain two to three weeks or longer. Karmilow states that the procedure when applied to the thigh and arm has been successful in 43.5 per cent. of the cases, while for the leg and forearm the number of cures has amounted to eighty per cent. Instead of ivory pegs, Riedinger has recommended bone pegs, which are capable of becoming firmly adherent to the bones.

If the procedures hitherto described do not prove successful, there is nothing left but to expose the false joint with the knife, to freshen the ends of the bones, to resect them, and then, when necessary, to fasten them together by sutures of catgut, sterilised silver wire, aluminium-bronze wire, silkworm gut, or by nails. The ends of the bones can be freshened by resecting them in the form of steps and thus fitting them together; or the pointed end of one fragment can be introduced into the medullary cavity of the other (see page 118, Fig. 111). Exposure of the false joint, followed by freshening the ends of the bones and uniting them with sutures or nails, is the safest method of treating all false joints of long standing, and if carried out with antiseptic precautions it is entirely free from danger. For nailing the bones, we use, as was said before, long, four-cornered steel nails, which are rendered perfectly sterile by polishing, boiling for fifteen minutes in a one-per-cent. soda solution, heating red-hot, and storing in a ten per-cent. solution of carbolic acid in glycerine. After nailing the bones together, an antiseptic protective dressing is placed over the wound, which is left open, and a plaster dressing is applied on the outside. The nails, which should protrude for a sufficient distance from the soft parts, are removed at the end of the third or beginning of the fourth week. Instead of nails, long steel pins can be used in suitable cases, or Gussenbauer's clamps, or metallic or bone rings.

If a considerable loss of substance has occurred in one of the two bones of the forearm or leg, we may either chisel out of the other bone a piece corresponding in size to the defect, and cause the ends of the bones to unite, with a corresponding amount of shortening, or the defect may be repaired by one of the usual methods of osteoplasty (see pages 607 and 610). In one case of loss of substance in the tibia Hahn successfully implanted the lower portion of the fibula into the upper fragment of the tibia. Quénu, Thiriar, and others

have successfully employed aluminium splints for pseudarthrosis; they were on the average ten centimetres in length, and were fastened subperiosteally by four to six screws. Bony union was obtained in five cases, and in three of these every other method of operative treatment had been unsuccessful. In two cases the splint healed in permanently, and in three it had to be removed.

The internal administration of lime, or, what is better, of phosphorus (Wegner), has been recommended for pseudarthrosis. Any constitutional or local anomaly which may be present must always, of course, be taken into consideration.

If all methods of treatment prove unsuccessful, care must be taken to alleviate the disturbance of function, as far as possible, by a suitable splint apparatus. If the peripheral portion of the limb has become so atrophic and flail-like as to render the wearing of a supporting appliance scarcely possible, amputation, particularly if it is the lower extremity which is involved, is indicated.

The Erosion of an Ivory Peg which has been driven into a Bone.—It is well known that ivory pegs which have been driven into a bone become roughened and appear as though portions of their surface had been gnawed away (Fig. 412). Polynuclear giant cells are found in the small cavities, and the same osteoclasts which are present during the normal process of bone absorption. The cause of this lacunar-bone absorption is partly to be ascribed to the action of an acid and partly to the pressure of the vessels and the cells of the surrounding tissues. I have shown that it is probably the carbonic acid which, *in statu nascendi*, during the metabolism of the tissues, sets free the lime in the ivory peg, and that then the decalcified ground substance which is left behind is dissolved by the alkaline fluids in the tissues (see page 583).

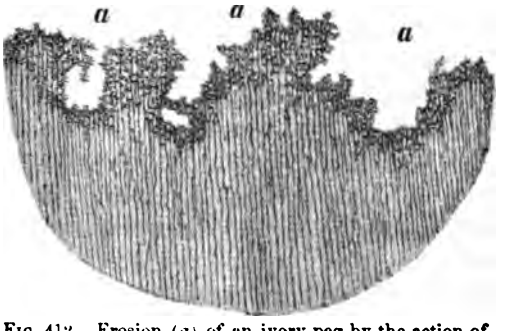


Fig. 412.—Erosion (*a*) of an ivory peg by the action of carbonic acid.

The Treatment of Fractures which have healed with Deformity.—Deformity in the healing of a fracture should be prevented by careful supervision of the point of fracture, or, in other words, of the position of the fragments while the process of healing is going on. The splints should be changed too often rather than too infrequently. If a fracture heals with so marked a displacement as to produce serious disturbance of function, the bones should either be refractured, or the point

of fracture exposed, chiselled through, and the ends of the bones then reunited in a good position. Those cases, as a general thing, are least amenable to treatment which have healed with considerable *dislocatio ad longitudinem*. The bones are broken under chloroform anæsthesia either by hand or by some special apparatus. The instruments used for directly fracturing the bones are called osteoclasts; the ones invented by Rizzoli and by Collin and Robin are very useful (see page 91). The open division of fractures which have healed with deformity is carried out by making an incision through the soft parts, thus exposing the points of fracture, and then dividing the bone with the hammer and chisel (osteotomy). The bone is not chiselled entirely through, but a small portion is left, which is broken by hand. When necessary, a wedge-shaped piece must be chiselled out of the deformed bone. Osteotomy of the bone is absolutely free from danger if the rules of asepsis are carefully observed. The wound is not sutured, but left open and packed with sterilised gauze, and directly over the protective dressing a plaster splint is applied, which is left in place until the wound has healed, though it is changed earlier if there is need of doing so. In cases of considerable shortening from mal-union of a fracture, the use of extension by a weight, after performing osteotomy, is very much to be recommended. Badly united fractures of the femur, for instance, occurring in adults and accompanied by much shortening, sometimes require powerful extension (by a weight amounting to twenty to twenty-five to thirty pounds), and surprisingly good results may be obtained, as both Schede and myself have observed. Under certain circumstances Schede recommends increasing the weight used for extension in the case of adults to as much as forty pounds.

Moritz and Meyer have used the electric current with success for exuberant callus (callus luxurians).

§ 102. **Contusions and Wounds of Bone.**—If a bone is crushed by a blow from a blunt object, we have especially to consider, in addition to the contusion of the bone substance, the injury to the overlying soft parts, the skin, the subcutaneous cellular tissue, and the periosteum. The course of contusions of the soft parts is described in § 92. Contusions of periosteum lead to a greater or less extravasation of blood into and particularly beneath the periosteum, which is called a hæmatoma of the periosteum. These periosteal and subperiosteal extravasations of blood usually terminate by being gradually absorbed. Not infrequently there develops, at the point where the periosteum has been contused, a traumatic, ossifying periostitis, in consequence of which the bone becomes temporarily thickened.

The anatomical changes which occur in contusions of bone tissue

proper consist in a more or less pronounced compression or splintering of the bone substance, such as happens after a thrust or blow, and to a marked degree in every fracture. In the medullary cavity an extravasation of blood is found proportionate in extent to the amount of violence exhibited. As is the case with fractures, the course of contusions of the periosteum, bone, and medullary tissue depends mainly upon whether an external wound is present or not. Only in the most exceptional instances of subcutaneous contusions of bone do inflammatory or suppurative processes occur, and when they do it is owing to the deposit of micro-organisms from the blood in the contused portions of bone and medullary tissue, or to the extension to the deeper parts of inflammatory processes beginning in the contused skin. Primary acute infectious osteomyelitis is probably sometimes caused by such a contusion of the medullary and cortical tissue. It is a well-known fact that tuberculosis may originate from some slight contusion of the bone, particularly in the case of children, for the reason that the tubercle bacillus finds in contused tissues and extravasations of blood conditions which are favourable to its development. The vascular arrangement in the medulla is such that solid impurities in the blood readily become deposited. The inflammation of bone to which mother-of-pearl turners are subject is an instance of this (see page 642).

The treatment of subcutaneous contusions of periosteum and bone consists at first in placing the injured part in a suitable (elevated) position, in the application of ice, and later in employing massage to promote absorption of the blood extravasated in the periosteum and soft parts. Inflammatory complications, suppuration, etc., are treated according to the general rules laid down in §§ 68–71.

Open Wounds of Bone.—The open wounds of bone have lost the danger that used to attend them before the introduction of the antiseptic method of treating wounds. By the latter means all infection is avoided, and even deep wounds which penetrate into the medullary cavity heal without complications. The most common wounds of bone are those occurring in fractures. True wounds of bone are such as are caused by a blow, or a thrust with a sabre, knife, axe, etc. In consequence of this violence there may be produced in the skull, for example, the fissures or cracks mentioned under Incomplete Fractures, which divide the bone either partially or completely. On the extremities, particularly the fingers, complete division of the bone and soft parts is frequently observed. Now and then, by paying strict attention to asepsis, phalanges or finger tips which have been entirely severed may be sutured in place and caused to reunite. Careful subcutaneous suturing of the periosteum with catgut and absolute immo-

bilisation of the affected part are of chief importance. I once saw a terminal phalanx which had reunited in this way come off again four weeks later in consequence of a violent blow, and then it could not be made to heal on a second time. If a piece has been taken out of the continuity of a bone by a sabre cut, for example, and there is no periosteum left at the spot in question, the bone will granulate very soon, and skin will gradually form over the granulating surface. Very often the loss of substance in a bone of the skull is not completely replaced by new bone, and persists as a more or less appreciable gap.

The repair of a wound in bone is essentially the same as that which takes place in fractures, and is described on page 602. Gunshot wounds of bone and soft parts will be discussed in conjunction with injuries of joints (see § 124).

§ 103. **The Inflammations of Bone.**—The inflammations of bone generally begin in the periosteum and in the medulla in the form of a periostitis and osteomyelitis. From these regions the inflammation extends to the bone substance proper and to the epiphyseal or articular cartilages, giving rise to a true ostitis or chondritis. The ostitis manifests itself either as an absorption of bone (rarefying ostitis) or as a new formation of bone (condensing ostitis). The inflammatory changes in the bone proper take place in the parts surrounding the vessels and in the medullary spaces. The pathological absorption of bone is, as a rule, analogous to the normal absorption—i. e., it takes place in the form of pit-like depressions, the so-called Howship's lacunæ (lacunar absorption of bone), which are hollowed out of the bone by the action of polynuclear cells—the osteoclasts, as they are called (Kölliker, Fig. 401). In this lacunar absorption of bone the lime salts and the ground substance are always dissolved more or less simultaneously. In a second form of absorption of bone—in halisteresis ossium—the lime salts become at first dissolved, the decalcified ground substance of the bone persisting for some time longer. The latter kind of absorption of bone takes place especially in osteomalacia (see § 109). The changes which occur in inflammation of cartilage consist mainly in a proliferation of the cartilage cells and in a fibrillary degeneration and necrosis of the ground substance of the cartilage.

§ 104. **Acute Inflammations of Bone, Acute Periostitis, and Acute Osteomyelitis.**—The acute inflammations of bone, in the form of an acute inflammation of the periosteum and medulla (acute periostitis and acute osteomyelitis), have been studied in their simplest form in § 101, under the subject of Callus Formation after subcutaneous fractures. In every instance where a suppurative periostitis and osteo-

myelitis occurs it is due, like any acute suppuration, to infection by micro-organisms. The infection has either taken place at the point where the injury was received, as in the case of compound fractures which are not treated antiseptically and open wounds of the periosteum, or it has spread from a suppurative inflammation of the surrounding parts, or, thirdly, it originates by infectious matter being brought from another portion of the body by the blood-vessels and deposited in the bone (hæmatogenous infection). The latter kind includes the metastatic inflammations of the periosteum and medulla occurring in pyæmia, typhoid, and scarlet fevers, etc. Such acute inflammations of the periosteum and medulla not only develop in the course of acute infectious diseases from metastasis of their poisons, but also occur in perfectly healthy individuals, and are due to micro-organisms which are carried to the bone in the blood from the external cutaneous covering, the intestinal tract, the lungs, etc., and there excite the various kinds of inflammation.

Acute Infectious Osteomyelitis.—The severest acute inflammation of bone is the primary acute infectious osteomyelitis and periostitis (Lücke) first described by Chassaignac as *osteomyelite spontanée diffuse des os* or *typhus des os* or *des membres*. This is chiefly observed in young people. Young growing bones, as a general thing, possess a more or less pronounced tendency towards inflammatory processes. An active development of new vessels takes place in growing bone, and the terminal loops of the vessels with their dilatations lie close to the epiphyseal cartilage; consequently solid impurities, especially micro-organisms, can be deposited in the cartilage from the retarded blood stream. Moreover, the filtration and deposition of micro-organisms and all solid impurities contained in the blood are rendered easy in the medulla of every bone, for the reason that the blood stream is not confined by walls as it passes through the sacculated medullary spaces. Osteomyelitis occurs most commonly in the femur of young subjects, possibly because this bone grows the most rapidly. According to Haaga's statistics, covering forty years' experience in the clinic at Tübingen, the disease occurs more frequently in men than in women, the proportion being 3.38 to 1. Acute infectious osteomyelitis is particularly common in certain regions, such as Switzerland, the mountainous parts of South Germany, and the coast of North Germany. Epidemics of very severe cases occur in these places. In other instances acute osteomyelitis is secondary, and occurs, for example, in the course of acute infectious diseases, such as measles, scarlet fever, small-pox, or typhoid fever (see page 641). We shall confine ourselves at present mainly to the primary acute osteomyelitis.

Etiology of Primary Acute Osteomyelitis.—Our knowledge of the etiology of primary acute infectious osteomyelitis has recently been advanced, particularly by Kocher, Rosenbach, Kraske, and others. It has been found that in the majority of cases it is caused by the yellow pus coccus, the *Staphylococcus pyogenes aureus*, less often by the *Staphylococcus pyogenes albus citreus*, or the *Streptococcus pyogenes* (see pages 327–331). Occasionally there is a mixed infection by various pus cocci. In fifteen cases of acute osteomyelitis Rosenbach found the *Staphylococcus pyogenes aureus* fourteen times, once with the chain coccus of cellulitis, and once with the white pus coccus (*Staphylococcus pyogenes albus*). Out of ninety cases of osteomyelitis Lannelongue found staphylococci in seventy (fifty-six times the *Staphylococcus aureus*), streptococci in only ten, pneumococci in three, and Eberth's bacilli in four; the streptococci and pneumococci were found chiefly in young children from one to five years of age. The *Staphylococcus pyogenes aureus* is more virulent than the *Staphylococcus albus*, and in case of streptococcus infection death is likely to occur promptly from sepsis. In some localities the disease is produced chiefly by the *Staphylococcus albus*. Osteomyelitis may also be caused by the typhoid bacillus, Fränkel's diplococcus, the *Micrococcus pyogenes tenuis*, the *Micrococcus tetragenus*, the *Bacillus pyocyaneus*, the *Bacillus pyogenes fœtidus*, and the *Bacterium coli commune*, as well as by the intravenous injection of the bacterium that produces lactic acid. Like any other acute inflammation and suppuration, osteomyelitis can be excited experimentally in animals by agents having a purely chemical action, such as turpentine or sterilised cultures, the latter producing their effect through the chemical products resulting from the metabolism of the pus cocci (Ullmann). In short, osteomyelitis can be excited by many varieties of micro-organisms and chemical agents, but the ordinary pus cocci are the most common cause of the disease. Consequently osteomyelitis is not due to a specific poison, as was believed to be the case for a long time, but it may be caused by any kind of micro-organism which excites acute inflammation and suppuration. Acute infectious osteomyelitis is essentially a phlegmon, so to speak, of the medullary cavity. By transferring osteomyelitic pus, or the above-mentioned micro-organisms, to the soft parts, cellulitis with suppuration is produced. The experiments of Becker and others show that after the introduction of pus cocci into the circulatory system or peritoneal cavity, typical acute osteomyelitis is particularly likely to develop if the affected bones have been previously contused or broken, for the reason that broken or contused bone offers a favourable medium for the growth of the pus cocci. Lexer, Canon, and others caused osteomyelitis in young growing rabbits by injecting the *Staphylococcus pyogenes aureus* into the jugular vein without injuring the bone; in fully grown animals the injection of the same caused inflammations of the muscles, joints, and internal organs similar to pyæmia. Jordan, Müller, and Sonnenburg regard osteomyelitis as mainly a pyæmia with localisation in the bone, and occurring chiefly in the growing period.

The origin of acute infectious osteomyelitis is to be explained on the supposition that the above-mentioned micro-organisms enter the circulation from some point in the skin, or in the lungs or intestinal tract, for example, par-

ticularly when at this point there is an inflammation, such as a furuncle, or even a slight interruption of continuity, and are carried off in the blood, from which they are deposited in the medullary portion of the bones of youthful subjects for the anatomical reasons mentioned before; here they develop, and give rise to severe suppurative or gangrenous inflammation with secondary involvement of the bone, periosteum, and frequently the joints. Colzi's experiments seem to show that the bacteria in osteomyelitis enter the body most frequently from the skin, less often from the lungs or intestinal tract. Osteomyelitis may result from any acute pus focus in any organ of the body in case the pus cocci are carried to the medulla of a bone. As we remarked before, traumatic lesions of bone favour the development of acute infectious osteomyelitis. How far catching cold conduces to its occurrence is a matter which cannot be determined, but the majority of surgeons believe that it exerts some influence. Acute osteomyelitis is either localised in one bone or in several at the same time, starting from one focus. In other cases the osteomyelitis located in one bone leads to metastatic osteomyelitis of other bones. Furthermore, acute osteomyelitis is either a primary disease or results secondarily from some infectious focus—e. g., a furuncle, suppurative inflammation of various organs or in connection with an acute infectious disease (measles, scarlet fever, typhoid, diphtheria, pyæmia, septicæmia, etc.).

Anatomical Changes in Acute Infectious Osteomyelitis.—The anatomical changes in acute infectious osteomyelitis vary with the species of bacteria which causes the inflammation. Generally speaking, osteomyelitis produced by staphylococci causes marked local destruction of the bone; that due to streptococci often results in inflammation of joints, and fatal general infection frequently follows before extensive suppuration has occurred in the bone. Osteomyelitis produced by typhoid bacilli does not run so acute a course as the usual kinds; the suppuration acts more like a cold abscess, and ulcerative and fungous forms often occur. The anatomical changes are in the main the following: At the outset there is a diffuse hyperæmia of the medulla, and, later, yellowish or greyish coloured foci of suppuration appear in it which not infrequently coalesce and form a single large collection of pus. In the severest cases there is observed a general suppuration of the medulla of the entire diaphysis—most commonly of the femur or tibia—with secondary collections of pus in the Haversian canals, between the periosteum and bone, in the periosteum, and in the adjoining soft parts. The periosteum probably becomes involved for the most part secondarily, and is the seat of inflammatory infiltration and swelling (serous, sero-fibrinous periostitis) or of suppuration. As a rule, the pus in acute infectious osteomyelitis is rich in fat, in consequence of the acute degeneration of the medullary cells. The suppurative separation of the epiphyses at their junction with the diaphyses is a pathological change of considerable importance, as well as the secondary development of inflammations of the neighbouring joints either in the form of a transitory mild serous or sero-fibrinous inflammation, or of a severe suppurative arthritis. Haaga states that in four hundred and seventy cases, permanent, slight, or pronounced changes remained in the joints one hundred and eighty-nine times. Curvatures or angular deformities of bones sometimes develop after osteomyelitis (see page 638).

Necrosis of the bone involved is a very frequent accompaniment of the inflammatory process, and varies in amount up to necrosis of the entire shaft of a long bone. In the mildest cases suppuration and necrosis do not occur, but there is only a condensing ostitis. The forms described as ostitis and periostitis are mainly the result of a mild non-suppurative osteomyelitis (see also pages 633 and 641). Acute infectious osteomyelitis terminates either in a complete *restitutio ad integrum*, with or without suppuration, or in a varying amount of necrosis of the bone, or in death, particularly from pyæmia and septicæmia. Pyæmia and septicæmia are both the cause and result of acute osteomyelitis—i. e., the latter either causes sepsis by the bacteria and their products being carried into the blood, or it is a secondary metastatic inflammation resulting from an already existing sepsis. Not infrequently encapsulated central bone abscesses are left behind which persist for years.

Osteomyelitis occurs either in a single bone, involving most commonly the diaphysis of the long hollow bones (femur, tibia), or as a multiple affection in different bones. In the latter instance there is a simultaneous infection of several bones, or the primary disease in one bone gives rise to metastases in other bones; the latter is by far most frequently the case. The short, flat bones most commonly affected are the clavicle, the ileum, and the scapula. After total necrosis of the clavicle the bone may be completely regenerated, its shape restored, and the function of the arm undisturbed.

Clinical Course of Acute Infectious Osteomyelitis.—The clinical course of acute infectious osteomyelitis varies greatly. The worst cases present the symptoms of a very severe constitutional disease, with high fever, delirium, rapid swelling of the affected bone, and death within a few days. In the mildest cases the local and constitutional manifestations are slight. The cases of moderate severity are probably the most common. The amount of constitutional infection does not always correspond to the extent of the local disease. The fever in the severe cases is, as a rule, very high, reaching 41° C. (104.1° F.). The disease generally begins with a chill two to three days after a traumatism, for example, or exposure to cold, and during the days immediately following the local disease can usually be readily made out in one bone, less often in several bones. The intense pain, the even swelling, the absence at first of any fluctuation or inflammation of the soft parts, and the pronounced disturbance of function are in general characteristic of the local disease of the bone. Many cases do not begin so acutely; on the contrary, they often commence very gradually. Occasionally the disease runs a course which presents the picture of an acute articular rheumatism with inflammation of the large joints. In these cases the osteomyelitis is always multiple, and the inflammation of the joints (secondary to disease of the neighbouring epiphyses) often goes on to suppuration.

The subsequent course of acute infectious osteomyelitis is in the majority of instances favourable. In the mildest cases complete *resti-*

tutio ad integrum takes place in two to three to four weeks without any noticeable suppuration. In the severest cases the suppuration of the medulla runs a very rapid course, accompanied by secondary suppuration of the periosteum and phlegmonous sloughing of the soft parts, sometimes with the evolution of gas. Death in such cases generally occurs from what looks like septicæmia with severe typhoid symptoms, or from pyæmia with secondary abscesses in the internal organs. Probably the most common termination is recovery, with necrosis corresponding to the amount of bone which has been affected. The necrosis is sometimes central and sometimes peripheral—i. e., it is confined to the bone adjoining the medulla or the periosteum. If there is extensive suppuration in the medulla and periosteum the entire diaphysis of a long bone may die. Not infrequently circumscribed collections of pus in the medullary cavity become encapsulated and form abscesses running a chronic course without necrosis, and leading to a characteristic diffuse enlargement of the affected bone. The suppurative separation of the epiphyses is another complication occurring in young subjects when the suppuration invades these parts. The epiphyseal separation, as in fractures or traumatic separations, is recognised by the abnormal mobility. Usually there is only separation of one epiphysis, which in the femur, for example, is the lower; only in rare instances are both involved. The separation of both epiphyses of a single bone appears to have occurred most commonly in the tibia.

The secondary inflammations of the joints which accompany acute infectious osteomyelitis are either acute or subacute serous inflammations, or severe suppurative forms, which may even be attended by the evolution of gas.

Sometimes, after an acute osteomyelitis has run its course, even when no extensive necrosis has taken place, the bone may be left abnormally soft. It may lose its strength to such an extent that curvature, angular deformity, or axial rotation of the diaphysis of a bone, like the femur, may be produced by muscular action and by the superimposed weight of the body (Stahl, Oberst, and others). In such cases of curvature or deformity the bones involved are remarkably porous, and at the point where the disease is located a fistula will generally be found which leads to a focus of rarefied bone with a sequestrum.

As Krause has correctly stated, the osteomyelitic cocci appear to possess great powers of resistance, since renewed formation of pus has been observed in old osteomyelitic areas even after the lapse of years. This is the explanation for those cases of multiple osteo-

myelitis in which the foci of the process have apparently completely disappeared, but in which, nevertheless, suppuration and necrosis subsequently develop.

Diagnosis and Prognosis of Acute Osteomyelitis.—The diagnosis of acute infectious osteomyelitis can be made from what has been stated about the anatomical changes and the symptomatology.

The prognosis, in the majority of cases, is favourable *quoad vitam*. But it must be borne in mind that the disease may cause death at any stage, so long as an escape is not provided for the pus by chiselling open the medullary cavity. Many cases, especially those caused by the streptococcus, run a rapidly fatal course. After the suppuration has subsided, it is mainly the extent of the necrosis, the amount of inflammation which has occurred in the joints, the condition of the epiphyses, etc., which determine the character of the case.

The Treatment of Acute Infectious Osteomyelitis.—The treatment of acute primary osteomyelitis has gained in efficacy with our knowledge of the etiology of the disease. In the treatment, a distinction must be made between the severe cases, which run a very acute course, and those which are mild and subacute. In the severest cases with high fever, a means of escape should be provided for the pus as soon as possible by making one or more openings into the bone—e. g., with a dentist's drill or an electro-motor apparatus (see page 90), and in case pus is found the medullary cavity is opened sufficiently in the form of a gutter with chisel and mallet. If operative measures are adopted early enough, the otherwise unavoidable necrosis of the bone and the breaking through of pus into a neighbouring joint may sometimes be prevented, and the course of the disease will thus be rendered milder and shorter than it otherwise would be. To avoid recurrences and to obtain speedy recovery, it will often be found a better plan, instead of making a gutter-shaped opening into the medullary cavity of a long, hollow bone, to remove all of the bone except a wall of cortex. This early scraping out of the infected medulla has recently been energetically supported by Tscherning (Copenhagen), Thelen, and others, and is in every respect a rational procedure, when it is remembered that we have to deal essentially with a cellulitis of the medulla; and in the case of any cellulitis it should be our aim to evacuate the pus at the earliest possible moment. It is not always easy to decide in what cases the aseptic opening of the diseased bone with the chisel should be attempted; moreover, many cases run such a rapidly fatal course that the correct diagnosis cannot be made at an early enough period. The evacuation of pus from bones, such as those of the pelvis, is difficult, and I have seen very severe cases involving just these bones where death occurred quickly. After opening the medullary cavity of a

long hollow bone, the suppurative focus should be scraped out, and, if necessary, the entire medullary cavity. The periosteum and soft parts should likewise be carefully examined for the presence of pus, and, if found, it should be let out by incision and drainage. Finally, the medullary cavity should be disinfected as carefully as possible with a one-tenth-per-cent. solution of bichloride of mercury or a three-per-cent. solution of carbolic acid, and then filled with iodoform gauze, over which is placed an antiseptic protective dressing. Instead of a dry aseptic dressing, wet dressings of one to two per cent. aluminium acetate may be employed to advantage. Immobilisation of the extremity in the best possible position by splints, etc., cannot be emphasised too strongly. Unfortunately, in spite of energetic and early operative local treatment, some of the severe cases will die in consequence of the systemic intoxication already present, which even an amputation or a total subperiosteal resection of the diseased bone will not always prevent. Complete resection of the bone—i. e., the removal of the diseased bone *in toto*—seems to me very inadvisable, as its efficacy has as yet not been sufficiently established. Amputation in the acute stage is rarely indicated, though it may be in the later stages, when suppuration becomes so excessive as to threaten to carry off the patient from exhaustion.

In the moderately severe and the mild cases the local treatment consists in the energetic application of ice, in placing the extremity in an elevated position, and in immobilising it as much as possible with a splint. Others prefer moist heat to ice for alleviating the pain. I consider that the application of iodine, which was formerly so much used, has but little effect. If there is marked swelling of the periosteum and the pain due to this is severe, even though no pus can be obtained by a test puncture, I nevertheless advocate early incisions to lessen the tension, and thus ease the patient's pain. Furthermore, it is possible by this means to prevent, or at any rate to limit, a subsequent necrosis of the bone. Not infrequently cases which were at the outset mild, become so severe that it may be necessary to chisel a groove into the medullary cavity and drain or pack the latter with iodoform gauze.

As regards the treatment of complications the following should be noted: Inflammations of joints are treated according to the general principles applicable to these affections (see Diseases of Joints). If suppuration occurs, the joint should be opened and drained as soon as possible. Separation of the epiphysis is treated in the same way as a fracture. Curvatures of bone following osteomyelitis can sometimes be overcome, after scraping out the osteomyelitic focus and removing

the sequestrum which may be present, by extension with a heavy weight (five to ten kilogrammes). The treatment of the necrosis which is so common a result of osteomyelitis is described in § 106. Defects in bone are repaired by one of the methods described on pages 607 and 610.

Amputation accompanied by Scraping out the Bone Stump.—Perkowsky practised amputation in eight severe cases of osteomyelitis, and then scraped out the medullary cavity of the diseased bone stump, removing in three cases the medulla of the entire stump with the sharp spoon, so that only a thin shell of bone was left. Necrosis did not take place in a single case, and a rapid recovery followed in all eight cases under iodoform dressings. Perkowsky thus avoided disarticulation or amputation of the limb at a higher point.

The treatment of acute periostitis occurring by itself is conducted according to the general rules which apply to inflammation. If the acute periostitis is suppurative, incision is employed; if not suppurative, antiphlogesis.

The Acute Traumatic Inflammations of the Periosteum and Medulla.—Acute traumatic inflammations of the periosteum and medulla are observed after injuries of various kinds, such as contusions, wounds of the periosteum, subcutaneous and compound fractures, wounds of bone, etc. Acute non-suppurative periostitis and osteomyelitis take place after every contusion and subcutaneous fracture. A typical non-suppurative periostitis occurs not infrequently in recruits in consequence of their drilling exercises; the excessive contraction of the fascia and the muscles of the leg causes localised thickenings of the bone, particularly in the front of the tibia (Laveran, Laub). The suppurative form is always caused by infection with bacteria which enter through some wound or circulate in the blood. This includes, moreover, the acute osteomyelitis of the amputation stump, which, especially in the days before antisepsis, terminated in death from pyæmia. At present we have learned to avoid this form of osteomyelitis with certainty in our amputations by employing antisepsis and asepsis. The anatomical changes and the cause of the acute (traumatic) periostitis and osteomyelitis are essentially the same as in the above-described spontaneous acute infectious osteomyelitis and periostitis.

Metastatic Inflammations of Bone.—The metastatic inflammations of bone in pyæmia, typhoid and scarlet fevers, measles, small-pox, etc., are either analogous to the spontaneous acute infectious osteomyelitis and periostitis, or they run a chronic course with the formation of circumscribed cold abscesses. The osteomyelitis following scarlet fever rather common (Chiari, Mallory). The inflammations of bone in the

course of typhoid fever usually occur during convalescence, are single or multiple, and are situated in the shaft of long bones and also in the ribs. They begin with rheumatic pains and run their course with fever. The abscesses have been found to contain pus cocci, virulent typhoid bacilli—even years after recovery from the typhoid—*Bacterium coli commune*, and other micro-organisms. These bacteria were found in some cases in combination, and in other cases each kind was found by itself. The bacteriological examination proved in some instances negative. In the cases of metastatic bone inflammation from plugging of the vessels by emboli, a corresponding necrosis of bone occurs which is called an "embolic necrosis." Such embolic necroses from obstruction to the afferent flow of blood are occasionally observed in endocarditic processes, when blood-clots with or without micro-organisms break loose from the growths on the endocardium and are swept away and lodge in the bones. Epiphyseal separations and secondary joint diseases, which were described above, may also accompany metastatic periostitis and osteomyelitis.

Growth Fever and Growth Pain.—In young subjects there is occasionally observed a marked temporary tenderness to pressure in the epiphyses of the long bones, especially the femur, humerus, and tibia, accompanied by inflammatory irritation of the neighbouring joints, with the manifestations of fever and a corresponding disturbance of the general health. Bouilly and Juillier have designated this condition as growth fever or growth pain. In most of these cases there is probably a real disease of the bones or joints: the children have pain because they are ill, and not because they are growing. The children in question show an excessive growth. Not infrequently rhachitis is present. Pure growth pains with fever are, in my opinion, extremely rare.

Embolic Foreign-Body Inflammations of Bone.—Great interest attaches to the embolic foreign-body inflammations of bone which are observed in mother-of-pearl turners and workers in woollen and jute mills. People employed in these occupations breathe in the particles of mother-of-pearl dust, wool, or jute, which then pass from the lungs into the circulation and lodge in the small arteries of the medullary portion of the bones, particularly the terminal arteries at the extremities of the diaphysis, and here excite embolic inflammation of the medulla with secondary involvement of the periosteum. As is the case with acute infectious osteomyelitis and periostitis, youthful individuals are the ones who are principally affected by these inflammations of the medulla in the diaphyseal ends of the bones and in the epiphyses. Gussenbaur, Englisch, and Levy have given accurate descriptions of the inflammations of bone to which mother-of-pearl turners are subject. The symptoms consist in very painful swellings, which usually appear suddenly at the ends of the diaphyses with marked swelling of

the periosteum. The course of the affection is generally subacute, and suppuration has as yet never been observed. *Restitutio ad integrum* ordinarily follows, the worst that happens being a thickening of the periosteum, which persists for a greater or less length of time. But if the turners resume their occupation, recurrences of the inflammation are frequently observed, which run a chronic course, with thickening of the spongy bones of the carpus or tarsus, or of the diaphyseal ends of the long bones.

Klein has described the bone disease of jute spinners. In this, too, there is an inflammation of the medulla and periosteum in the region of the epiphyseal cartilages, accompanied by severe pain. A considerable growth of epiphyseal cartilage usually takes place, giving rise to secondary curvature of the bones, particularly the tibia. In this affection also suppuration or necrosis never occurs.

§ 105. **The Chronic Inflammations of Bone** (*Chronic Periostitis, Ostitis, and Osteomyelitis*).—The most important chronic diseases of bone are the mycotic, of which the tubercular, syphilitic, and actinomycotic inflammations of bone are prominent examples. Furthermore, acute infectious diseases, such as measles, scarlatina, typhoid fever, etc., may be followed not only by acute inflammations of bone, as mentioned above, but also by inflammations which are at first latent, and then subsequently manifest themselves as affections running a chronic course. The chronic inflammation of the ribs which follows typhoid fever is an example of this class of cases (see page 617). The other chronic inflammations of bone are mostly secondary to preceding acute inflammations, and include, as a terminal stage of the latter, necrosis. Chronic inflammations of bone are also sometimes the result of the extension to the latter of chronic inflammation in the surrounding parts. The changes which occur in bone in consequence of chronic inflammation consist either in a destruction of the bone substance (caries, necrosis) or in a reactive new formation of bone.

Chronic Periostitis.—Among the various forms of chronic periostitis, mention should first be made of the chronic fibrous form. In this variety tough, fibrous thickenings of the periosteum develop, sometimes with absorption of the superficial portions of the bone (caries superficialis), and sometimes with new formation of bone. In the latter instance the process is an ossifying periostitis.

Periostitis Albuminosa or Mucinosa (Non-purulenta).—Poncet and Ollier were the first to describe a peculiar form of periostitis under the name of periostitis albuminosa (ganglion periostale), concerning the nature of which different authorities hold very divergent views. The affection attacks almost exclusively the ends of the diaphysis of the long, hollow bones in young sub-

jects from fifteen to twenty years of age, and involves not only the periosteum but frequently the bone also (ostitis albuminosa). Schlange has proposed calling it periostitis and ostitis non-purulenta, and Riedinger periostitis mucinosa. As a rule, the disease begins with severe pain, swelling at the lower end of the diaphysis in the neighbourhood of the epiphyseal line, and fever, as is the case in acute primary osteomyelitis. After a few days the fever and pain disappear, and the swelling of the periosteum and bone becomes more and more prominent. There will be found at the diseased point, instead of pus, either a bloody serous or a hydrocele- or synovial-like fluid which has the consistency of tenacious mucus. The fluid lies either beneath the periosteum, or within it in the form of a cyst, or on its outer surface, and in the latter instance there is also a diffuse œdematous swelling of the surrounding soft parts. In my opinion the disease is at the outset an acute or subacute non-suppurative, non-serous osteomyelitis and periostitis, which is not a disease *sui generis*, but is caused by various factors, particularly by attenuated pus cocci (staphylococci); in some cases it may be of tubercular or syphilitic nature. Dor found in one case the *Bacillus cereus citreus*. Vollert states that a mucoid metamorphosis of the leucocytes takes place in this affection. Its course is very chronic, and necrosis of the bone is often present. The disease is very rebellious to therapeutic measures and recurrences frequently take place, or fistulæ may persist for months or years. The best treatment consists in incision and energetic scraping out of the underlying diseased bone, with or without chiselling an opening into the medullary cavity. Cystic formations should be carefully extirpated.

In the chronic ossifying periostitis the new formation of bone is either limited to a circumscribed portion of the bone, giving rise to what is called an osteophyte (Fig. 413), or diffuse hypertrophies—hyperostoses, as they are called—are developed, in consequence of which thickenings of the bone resembling elephantiasis result (Fig. 414).

Fig. 413.—Osteophyte (Pathological Museum at Leipsic).

In addition to chronic fibrous and chronic ossifying periostitis, we recognise a chronic suppurative periostitis, which sometimes is the terminal stage of an acute periostitis and sometimes develops gradually as a disease by itself, and chiefly comes into consideration as a concomitant phenomenon of necrosis or caries of bone. In chronic suppurative periostitis we have to deal, for the most part, with specific

processes, such as tuberculosis, syphilis, or actinomycosis, and also with necrosis of bone from various causes. Tubercular periostitis is either primary or secondary to tuberculosis of bone or its medulla, or of the surrounding soft parts.

FIG. 414.—Hyperostosis (elephantiasis) of the femur (Pathological Museum at Leipsic).

Treatment of Chronic Periostitis.—Chronic non-suppurative periostitis should be treated briefly as follows: First of all its cause should be determined and proper steps taken to remedy it. To relieve the tension, pain, and local inflammatory symptoms, incisions and hydropathic applications can be used with advantage. It is also an excellent plan to paint the parts with tinct. iodi fortior alcoh. (five parts iod. pur. to 30.0 of alcohol). Compression by the elastic bandage is of use for the fibrous thickening and osteophytes; but troublesome osteophytes, occurring, for example, in connection with an ulcer of the leg or some other disease of the soft parts, should be removed with the hammer and chisel.

The treatment of chronic suppurative periostitis is likewise mainly determined by the cause, and we shall discuss this disease more fully under Tuberculosis, Caries, Necrosis, &c. (see also Syphilis, § 84, and page 652).

Tuberculosis of Bone.—One of the most important and by far the most common of chronic bone diseases is tuberculosis (ostitis tuberculosa, caries tuberculosa or fungosa), which occurs chiefly as tubercular periostitis and osteomyelitis, and leads to extensive destruction of bone—to caries, as it is called (Fig. 415)—and to necrosis. Volkmann, Billroth, König, Ollier, and others have won lasting honours by their studies upon the subject of tuberculosis of bones and joints, and Robert Koch has greatly advanced our knowledge of the etiology of tubercular inflammation by demonstrating and obtaining in pure cultures the tubercle bacillus (§ 83). We now know that all those forms of inflammation which affect bone, and have been designated caries, spina ventosa, scrofulous or fungous inflammation of bones

and joints, tumor albus, etc., are in the main true tubercular inflammations.

Tubercular inflammation of bone occurs most commonly in young individuals—i. e., in growing bone—for the reason mentioned before, namely, that the formed foreign elements circulating in the blood, particularly the tubercle bacilli, are more readily deposited in the branches of the vessels in growing bone, although tuberculosis also occurs during the later years of life, and may be met with even in extreme old age. The poison of tuberculosis, the tubercle bacilli, are generally carried to the bones by means of the blood-vessels, as can be easily proved by experiments on animals. Injuries of bone, as we remarked before, favour the development of tuberculosis. Tuberculosis of bone may, moreover, be due to the direct extension to the latter of a tubercular process in the surrounding tissues, such as the skin, subcutaneous tissue, tendon sheaths, synovial membrane, etc. Tubercular inflammations of the vertebræ and of the bones of the hands and feet are the most common.

Anatomical Changes in Tuberculosis of Bone.—Tuberculosis of bone almost always begins with the formation of circumscribed foci in the periosteum, in the epiphyses of the long bones, in the medulla, or in the spongiosa of the short bones (Fig. 351); less commonly the disease is more

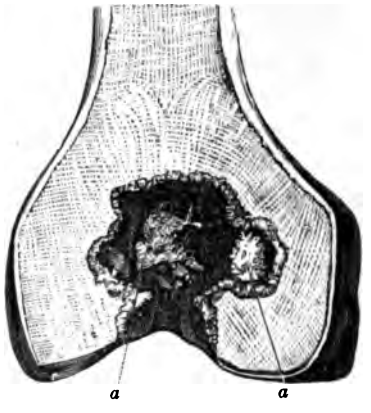


FIG. 415.—Tuberculosis of the lower epiphysis of the femur, with two sequestra (*a*). The process has broken through into the knee-joint (Weber).

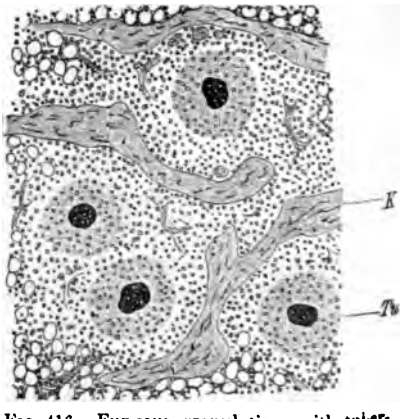


FIG. 416.—Fungous granulations with tubercles (*Tu*) in the cancellous portion of the talus: *K*, intact trabecula of bone.

diffuse. The tubercular focus often remains for a long time the size of a pea or a hazel-nut, and then enlarges by direct extension from its edges or by the development of new foci in the region surrounding the primary one. The individual foci then coalesce, and thus large tubercular areas originate. Not infrequently several distinct foci are observed in one and

the same bone, or tubercular inflammations occur in different bones at the same time or one after the other. The tubercular focus is made up of the characteristic tubercles which originate from the lodgment and growth of the tubercle bacilli, and have been minutely described on page 415. Wherever a tubercle focus develops in bone (Figs. 415 and 416), caries results—i. e., the bone disappears in the form of lacunar absorption (see Fig. 401)—while the focus itself sooner or later becomes the seat of a cheesy degeneration beginning in its centre. If the bone has not been destroyed at the time that caseation of the tubercular focus occurs, death of the bone then takes place *in toto*—i. e., a so-called tubercular sequestrum forms which becomes separated from the surrounding parts by a demarcating suppuration. In the later stages the tubercular sequestrum lies completely free in a cavity of greater or less size, containing cheesy, flocculent pus, with or without fistulæ opening externally (Fig. 415). In general the characteristic tubercular sequestrum is a larger or smaller caseated concretion of bone through which has grown tubercular or caseous granulation tissue. Very often the entire tubercular focus becomes softened and liquefied *in toto* without the formation of a sequestrum. The central abscesses of bone, which exist for years, are partly due to tubercular processes, partly to a preceding primary acute infectious osteomyelitis, and partly to metastasis in the course of acute infectious diseases.

A reactive formation of bone often takes place around the tubercular focus in the bone or its medulla, causing it to become more or less completely enclosed by thickened, sclerotic bone tissue. In the pronounced cases of sclerosis of bone the bony structure becomes as dense as ivory (so-called eburnatio ossis), and the medullary cavity may be completely obliterated. But in other instances all traces of reactive hyperplasia of bone are absent, even though the tubercular inflammation has existed for years.

In some cases there are also formed sacculated collections of pus—cold abscesses—which are enclosed in a characteristic so-called pyogenic membrane consisting of connective tissue and tubercular granulation tissue. The abscesses either rupture externally in the region where they originated, or the force of gravity causes them to sink lower. In the case of tubercular inflammation of the dorsal vertebræ, for example, they descend along the anterior surface of the vertebræ, following the course of the psoas muscle, and appear beneath Poupart's ligament (so-called spinal abscesses). These spinal abscesses extend in a perfectly typical manner, which is governed by the anatomical conditions—i. e., they follow the natural spaces between the tissues corresponding to the arrangement of the fasciæ and aponeuroses.

The caries which accompanies tuberculosis is often—in the case of the vertebræ, for example—very considerable. In consequence of this there develops in the back the so-called kyphosis or Pott's hump, named after the English surgeon Percival Pott, who first described this disease. Marked destructive changes also take place in the small bones and articular ends of the long ones, leading to deformities of various kinds, with subluxations and complete dislocations of the deformed articular extremities of the bones. In the fingers and toes tuberculosis usually occurs as a tubercular osteomyelitis, with a spindle-shaped enlargement of the bone (*spina ventosa*). In this condition the cortex of the bone becomes constantly thinner in consequence of

the tubercular osteomyelitis, while at the same time, as a result of the reactive periostitis, osteophytes are formed. Spina ventosa often heals without suppuration or necrosis having taken place, and with a spontaneous and complete *restitutio ad integrum*. The same form of tuberculosis also occurs in the long bones, such as the tibia and femur.

The most common site of bone tuberculosis in the long bones, whether located in the periosteum or in the interior of the bone, is in the region of the epiphyses. This is the reason why secondary tuberculosis of the joints is so common (see § 114, Tuberculosis of Joints). Tuberculosis of the diaphysis of a bone is comparatively rare—a fact of great diagnostic importance, especially in the case of adults. Consequently, if the shaft of a bone is diseased, particularly in an adult, we think of syphilitic or some other bone disease before tuberculosis.

As regards other bones, tuberculosis is especially common in the bones of the skull, in the orbital portion of the superior maxilla, in the ribs, and particularly in the spinal column and the bones of the carpus and tarsus.

The microscopical changes in tuberculosis of bone (Fig. 416) are the same as in tubercular inflammation elsewhere. Koch's tubercle bacilli will be found most abundantly where the tubercular process is beginning, the best method of staining being that of Ehrlich's, with fuchsin or gentian violet. Nevertheless, their demonstration in tuberculosis of bone is sometimes very difficult, or even impossible—a fact which we noted before. In tuberculosis of bones and joints Müller frequently found peculiar bodies resembling fat drops, which not uncommonly were surrounded by minute granules, and, like these, were characterised by taking on a deep red or violet stain. These bodies probably bear some relationship to the bacilli.

The Clinical Course of Bone Tuberculosis.—The clinical course of tuberculosis of bone is usually very chronic. There are often symptoms of tuberculosis in other organs—the lungs, for instance—at the same time. Heredity is important—i. e., tuberculosis of the parents or grandparents or other near relatives. Quite often it happens that for a long time symptoms peculiar to tuberculosis of bone are absent; severe pain especially may long be missed, unless a neighbouring joint, the periosteum, or overlying parts are attacked by the tubercular inflammation. In the majority of instances the symptoms pointing to tubercular inflammation will not make their appearance till after the disease has existed for months, the development of an appreciable tumour, particularly if the tuberculosis is periosteal, being the first intimation of the process. But even if the tuberculosis is located in the bone or medullary cavity, an appreciable tumour will sometimes be formed after several months in consequence of a thickening of the bone, while in other instances, though the tuberculosis may have existed for years, all swelling will be absent. Under these conditions the diagnosis can often only be made when the periosteum begins to become involved in the inflammation, and there is tenderness on pressure over the area in

question, or when œdema of the skin is present. As the tuberculosis advances the symptoms become more pronounced, especially the swelling at the diseased spot, the pain, particularly if the tuberculosis is located in the medulla, the disturbance of function, the development of fistulæ, burrowing of pus, etc. The disturbance of function is most pronounced in tuberculosis of the epiphysis in the neighbourhood of a large joint like the hip or knee. The tumefaction accompanying tubercular infiltration of the periosteum or medulla is either due to osteophyte formation, or the bone is puffed out, as it were, by tubercular osteomyelitis, in the manner which we described as occurring in spina ventosa of the phalanges of the fingers. In this spina ventosa of the fingers the bone may feel firm, or elastic and thin. After a certain length of time the tubercular pus works its way outwards and breaks spontaneously through the skin, and the thin liquid, usually mixed with cheesy flocculi, is discharged. Fistulous ulcers with a cheesy base and undermined edges then develop from the fistulæ. If a probe is passed through the fistula it either immediately comes in contact with the bone, or penetrates into the medullary cavity. The other secondary manifestations of tuberculosis, the cold or congestion abscesses, etc., have been sufficiently described, and we need only call attention to the fact that the latter do not heal up until the original focus which gave rise to them has disappeared. Their course is usually very tedious, especially in the case of tubercular inflammation of the spine. The tubercular inflammations of joints are discussed in § 114. A tubercular deposit in the periosteum or medulla of an epiphysis, lying in immediate proximity to a joint, often works its way to the surface *extra-articularly*, and leaves the joint intact.

The general health in tuberculosis of bone is very often but little or not at all affected. There is frequently a slight fever, varying with the extent of the process. It is a common occurrence to find that the general health is only slightly disturbed even when extensive multiple tuberculosis is present. In general the fever is most pronounced *before* the tubercular inflammation has extended beyond the bone, but it is usually slight, and, as a rule, disappears more or less completely when the inflammation has worked its way to the surface of the body. High fever is most likely to occur in case of secondary infection with pus cocci.

Diagnosis of Bone Tuberculosis.—The diagnosis of tuberculosis of bone is easy in the case of primary tubercular periostitis, particularly if the bone is superficial, and the characteristic swelling, tenderness on pressure, etc., are present. The diagnosis of bone tuberculosis may occasionally be doubtful for some time, but still its beginning and subsequent course in different parts

of the body, as we shall see in the Regional Surgery, is generally so typical that the diagnosis is not very difficult (see also § 83, Tuberculosis).

Prognosis of Bone Tuberculosis.—As regards the termination and the prognosis of tuberculosis of bone, I must refer the reader to what has been stated in § 83. Suffice it to say that the location of tuberculosis of bone plays a very important part as regards prognosis—i. e., in so far as it determines whether the existing focus can be completely removed by operative measures at the earliest possible stage, or whether other local treatment, such as iodoform injections, can be employed. If the latter is impracticable, as may often be the case in tuberculosis of the vertebræ, spontaneous recovery can probably only take place when the focus is not too large. In the majority of instances the tubercular disease steadily progresses or very often leads to tubercular systemic infection. Recurrences in tuberculosis are pretty common, and permanent cures do not occur so frequently as many enthusiasts believe (see § 83).

The Treatment of Tuberculosis of Bone.—In the first stages of a developing tuberculosis of bone the treatment is purely symptomatic (rest, immobilising dressings, ice, good food, fresh air, etc.). As soon as possible I then begin in suitable cases parenchymatous injections of sterilised ten per cent. iodoform oil, or the iodoform glycerine of Bruns, which I can most heartily recommend (two to eight grammes every two to four weeks). The iodoform and oil are sterilised separately by heating them in a sterilising apparatus to 100° C. (212° F.); the sterilised materials are then cooled and made into a ten per cent. iodoform mixture in a sterilised vessel. Instead of ol. olivæ, Böhm recommends ol. amygd. dulc., in which is dissolved fifty per cent. of iodoform. If the iodoform oil is prepared in the manner described above, we avoid the injurious effects or poisonous manifestations of the iodoform, which are mainly caused by the liberation of iodine. The latter is particularly apt to be set free if the iodoform and oil are sterilised together at high temperatures when in the form of an emulsion. Lannelongue praises the results obtained by the injection of strong solutions of chloride of zinc into the periphery of the tubercular focus; a contracting, cicatrix-like tissue is thus produced, which forms an obstruction to the spread of the tubercular process and causes the death of the tubercular focus. I have little to say in favour of parenchymatous injections of three-per-cent. solutions of carbolic acid or arsenic. Nannotti recommends oil of cloves (ten per cent., with olive oil); Reboul, naphthol camphré obtained by mixing and heating one hundred parts of finely powdered β-naphthol with two hundred parts of finely powdered Japan camphor. The oily liquid of naphthol camphré is insoluble in water, but miscible with fats, ether, alcohol, and chloroform, and must be kept in a dark bottle. The remedy can be employed in various ways—as a wash, an injection, etc.

Bouchard states that its toxic dose for adults is about two hundred and fifty grammes. For other remedies, including cinnamic acid, see page 429.

If treatment by drugs proves unsuccessful, and a distinct focus of disease or of pus is present, operative treatment should be undertaken—i. e., the tubercular deposit should be removed as soon as possible, with strict regard to antisepsis. Operations on the extremities are performed with the use of an Esmarch bandage, which renders it possible to easily distinguish the healthy from the diseased parts. A free incision should always be made, in order that the focus may be inspected throughout its entire extent. Electric illumination is often useful for this purpose. If the tuberculosis is in the medulla, the bone should be opened sufficiently with the chisel and hammer, and the tubercular focus energetically scraped out with the sharp spoon. The scraping-out process must be continued until healthy, firm bone is reached. Even when the entire medullary cavity of a long bone has to be thus scraped out, necrosis will not occur if only the wound in the bone heals aseptically. To prevent recurrences and to render speedy recovery possible, extensive removal of the bone is advisable, leaving only a thin wall of cortex intact. Free sequestra should be extracted; infected soft parts in the neighbourhood of the diseased bone, abscess membranes, etc., should likewise be removed with the greatest care by scissors and forceps. After having scraped out the tubercular deposit in the bone, the resulting cavity should be filled with ten per cent. iodoform oil and packed with iodoform gauze. Billroth's method is most excellent and efficacious. The tubercular cavity, in case it has not opened externally before the operation, is immediately filled with ten per cent. iodoform oil or iodoform glycerine, and hermetically closed after all tubercular tissue has been removed with the sharp spoon. The iodoform acts more effectively in the absence of air.

If any recurrences take place, they are soon recognised by the persistence of fistulæ with fungous tissue. The secondary operation should not be delayed too long. Operations must often be performed two, three, or more times, with short intervals, before a complete cure is obtained. The cold abscess, which used to be a *noli me tangere* to the old surgeons on account of the pyæmia which so frequently followed the operation, must always be opened at the earliest possible moment, scraped out and drained; or, after evacuation of the pus, iodoform emulsion may be injected into the cavity and the incision closed by sutures. The treatment of tubercular inflammations of joints will be discussed under the subject of Diseases of Joints (§ 114). The indications for amputation and resection are described on pages 119 and

135. All operations in cases of tuberculosis should be performed with the greatest care and most rigid asepsis. We mentioned, in first speaking of tuberculosis, that general miliary tuberculosis may occasionally follow operations on tubercular foci, as well as vigorous movements of joints affected with tubercular disease.

Iodoform and iodoform gauze are the best materials for dressings in cases of tuberculosis, and large wounds may be packed with them. Instead of packing with iodoform gauze, Schede's plan of obtaining healing under an aseptic blood-clot without drainage is also very serviceable after scraping out the tubercular deposit (see page 109).

The treatment of tuberculosis of bone with Koch's tuberculin is discussed on page 421. I have obtained no permanent cures by this means, and sometimes matters have been made decidedly worse. Other surgeons have had the same experience.

In tuberculosis it is very important that the constitution of the patient should be strengthened by energetic general treatment, in the manner described on pages 429 and 434.

The Syphilitic Diseases of Bone.—Syphilis of bone occurs in the later stages of the disease (§ 84), either in the form of death of bone, as caries and necrosis, or as an ossifying inflammation of bone. The inflammation of bone characteristic of syphilis is the gummatous periostitis and osteomyelitis—i. e., the formation of gummata or syphilomata in the periosteum or medulla. The periosteal gummata take the form of flat, elastic swellings, which on section reveal a gelatinous consistency. In the later stages a fatty, cheesy, or a suppurative degeneration takes place, with or without shrinkage, to firm fibrous thickenings. The periosteal gumma is very apt to occur on the skull, and also not infrequently in the periosteum inside the cranial cavity, less often on the clavicle, and rarely on the diaphyses of the long bones. The epiphyses of the latter and the short bones are, almost without exception, exempt from gummata.

The osteomyelitic gummatous nodes are soft or more fibrous gelatinous formations, varying from about the size of a pea to that of a nut, and usually cheesy in the centre. They are sometimes multiple, being found, for example, on the skull, on the phalanges, and, according to Chiari, also on the long bones, the femur and tibia being the most frequently affected.

Both periosteal and osteomyelitic gummata destroy the bone to a greater or less extent, and lead to a varying amount of superficial or central caries with necrosis. In consequence of this death of bone fractures readily occur, and not infrequently are followed by pseudarthrosis. The syphilitic caries with necrosis is particularly apt to make

its appearance on the skull, and sometimes is very extensive (see Regional Surgery). A reactive new formation of bone also occurs as a result of the gummatous periostitis and osteomyelitis; it leads to the development of osteophytes of varying dimensions, and also to hypertrophy and sclerosis of the bone.

The gummata either disappear under appropriate antisyphilitic treatment by becoming gradually absorbed and replaced by dense cicatricial tissue or newly formed bone tissue, or else a spreading destruction and necrosis of bone develops, the gummata open externally, etc.

Apart from the reactive development of new bone with the formation of osteophytes and diffuse hyperostoses accompanying gummata, there is also an independent ossifying syphilitic ostitis, a periostitis and osteomyelitis, which occur alone.

In congenital syphilis there is observed a characteristic disease of the bones in the neighbourhood of the epiphyses, consisting in some cases in an abnormity in the deposit of lime, and in the formation of medullary spaces such as occurs in rhachitis. This syphilitic rhachitis is not very common. But in other cases of congenital syphilis a very characteristic localised disease is present in the epiphyses, particularly in the part near the articular and epiphyseal cartilages. This syphilitic osteochondritis of infants, first described by Wegner, is in fact a common though not a constant manifestation of hereditary syphilis. The disease consists in the formation of greyish-red or yellowish-grey foci in the medulla of the epiphyses in the neighbourhood of the articular and epiphyseal cartilages. The bone becomes replaced by a soft granulation tissue, and the cartilage itself is in a state of inflammatory growth. Separation of the epiphysis sometimes occurs in syphilitic osteochondritis, as it does after acute infectious osteomyelitis. Kassowitz found this condition nine times in thirty-three cases. Epiphyseal separations have also not infrequently been observed in still-born syphilitic children (Haab, Veraguth, etc.), but under these circumstances the separations may possibly have been caused by putrefactive changes as well as by the syphilitic osteochondritis.

The course of the syphilitic inflammations of bone, which occur especially in the later so-called tertiary period of the disease and in the cases which have been improperly treated, is for the most part very chronic and marked by frequent relapses. They have been wrongly ascribed to the effects of mercury. Ostitis due to mercury is only observed as a result of salivation ulcers on the jaws. Traumatism appears to play an important part in the syphilitic inflammations of bone. The severe pains (dolores osteocopi), which occur principally at night, are often characteristic.

The treatment of the syphilitic inflammations of bone consists : the adoption of a general antisyphilitic regimen (see § 84). The loc treatment of the syphilitic metastases is conducted according to gener principles, and is similar to that briefly described for tuberculosi of bone.

Chronic Bone Abscess.—We have made repeated mention of the so-called chronic bone abscess which occurs, for example, after acute infectious osteomyelitis and tuberculosis of bone. It is always infectious in its nature and arises in various diseases, and is not, as was once believed, an independent disease, but always a symptom or a result of a pre-existing specific disease. Hence it follows that the causes of abscess of bone vary greatly. The acute suppurative inflammations of the periosteum and medulla, the tubercular and the syphilitic inflammations of bone, are particularly likely to give rise to the development of chronic bone abscesses. In the majority of cases acute infectious osteomyelitis is the cause of chronic bone abscesses; the pus usually contains staphylococci which have been found to be virulent even after the abscess has existed for 30 to 40 years. Bloch has reported 15 cases of chronic bone abscess of which 11 involved the tibia; the time intervening between the primary disease and admission to the hospital varied from 4 months to 42 years (once 11 years, once 12 years, once 14 years, three times 16 years, once 20 years, and once 42 years).

The symptomatology and treatment of abscess of bone can be inferred from what has been said concerning acute and chronic suppuration of bone.

Other Bone Diseases: Actinomycosis; Glanders.—Among other chronic diseases of bone, I should mention actinomycosis and the circumscribed cheesy or suppurative inflammations which occur in the periosteum and medulla in the course of glanders. Both diseases have been described in § 78 and § 86.

Ostitis deformans.—Ostitis deformans, first described in 1876 by Paget, Czerny, and Recklinghausen, is a chronic inflammation of bone occurring in adults in which the bones always remain intact. It involves the long bones, the skull, the vertebræ, and the pelvis, and is characterized by hypertrophy and softening of the bone, sometimes painful and sometimes painless, and resulting in a bending of the same. Malignant tumours sometimes develop. Two varieties can be differentiated, a painful and a painless. The former is, the more common, and begins usually in the lower extremities, with thickening and subsequent bending of the bone. The painless variety usually begins in the upper extremities of females. The disease is only rarely confined to sing

bones. Thiberge and Joncheray have collected 60 cases from literature (40 from the English and 15 from the French literature). The average age of the patients was about 50 years. In exceptional cases it begins in childhood. The etiology of the affection, which is in fact a bone disease *sui generis*, is not clear. Recklinghausen classifies the disease closely with osteomalacia, and regards it as a decalcifying process involving the entire osseous system, with attending absorption and new formation of bone. Virchow thinks that it may result from disturbances in development. The treatment is symptomatic.

§ 106. **Necrosis of Bone.**—We have repeatedly spoken of the death or necrosis of bone or of a certain portion of bone when discussing the subject of Injuries and Inflammations of Bone.

The causes of necrosis of bone are sometimes inflammatory and sometimes traumatic in their nature. In typical necrosis of bone there is almost always an interruption of the afferent flow of blood, less often a direct death of the bone substance. Among the special causes of necrosis the diseases of the periosteum and medulla are the most important. Suppurative periostitis very frequently leads to necrosis; but every suppurative periostitis, as such, will not cause necrosis of bone until it has existed a long time and has extended to the contents of the Haversian canals. The suppurative periostitis is frequently the result of a necrosis due to other causes.

Necrosis is also produced by the various forms of ostitis and osteomyelitis when the bone tissue becomes unable to obtain nourishment, owing to the destruction of the medulla and the contents of the Haversian canals. In this class of cases comes, for example, the necrosis from suppurative osteomyelitis and tuberculosis of bone, mentioned in a previous chapter.

Suppurative inflammations of the surrounding parts and ulcerative processes which extend to and destroy the periosteum likewise lead to necrosis. In this manner is caused, for example, the necrosis of the nasal bones, which occurs in the course of syphilis from the extension of ulceration in the nasal mucous membrane to the deeper parts (ozæna syphilitica).

The necrosis occurring in the course of typhoid fever and the acute exanthemata is due in some instances to metastatic periostitis and osteomyelitis, while in others it is probably a kind of inanition necrosis which is the result of the general disturbance of nutrition. As a matter of fact the state of the nutrition of such individuals is generally extremely bad, and they suffer for the same reason from gangrene of the ears and nose.

In rare instances necrotic foci in bone originate from emboli. Volk-

mann saw a multiple necrosis of the astragalus and tibia which followed the formation of coagula on the mitral valve in endocarditis. In these cases we generally have to do with multiple capillary emboli, and in the case of infectious processes these emboli may consist of micro-organisms which have entered the circulation. Embolism of a single nutrient artery of the bone would probably never be followed by appreciable consequences, for the reason that a collateral circulation readily develops, and the blood is carried to the bone by very many and for the most part very small vessels.

The phosphorus necrosis, first described by Lorinser, of Vienna, in 1845, is extremely interesting. It is observed in people employed in the manufacture of phosphorus matches, and is due to the injurious effects of the vapour of phosphorus. Phosphorus necrosis only affects the bones of the face, and selects the jaw almost always—the inferior maxilla more frequently than the superior. The disease regularly begins with inflammatory disturbances in the periosteum (phosphorus periostitis, Wegner), especially where there are diseased (carious) teeth. At first a chronic ossifying periostitis usually develops, then, as a result of infection by bacteria in the oral cavity, suppuration and gangrene follow between the periosteum and new bone, or between the new and old bone. Sometimes, though rarely, the disease begins immediately with suppuration and necrosis without a preceding ossifying periostitis. The entire lower jaw may become necrotic, especially if the process is not arrested by early removal of the focus of disease. Häckel states that the average duration of the disease from the time the periostitis begins till the suppuration and necrosis of the under jaw, for example, ceases, is, when the disease is left to itself, for the inferior maxilla two years and nine and a half months, and for the superior maxilla one year and two months. Since the manufacture of phosphorus matches has become less extensive, and strict hygienic regulations have been enforced in the factories, phosphorus necrosis has become rare; but it still occurs in regions such as the Thuringian Forest, where the making of phosphorus matches is carried on as a family industry.

Necrosis develops after a traumatism, particularly if portions of the bone are completely torn off or separated from their attachments—a fact which we learned when discussing fractures (see § 101). We stated at that time that in fractures which heal aseptically and in those which are subcutaneous, pieces of bone which have been completely detached may again heal in place and not undergo necrosis. After subcutaneous dislocation of the astragalus, Winiwarter observed total necrosis of the bone occur in two instances in spite of its having been carefully replaced. Furthermore, when a bone has been severely splintered and

crushed, circumscribed necrosis is particularly apt to develop if the arterial vessels in the medullary space or narrow Haversian canals are compressed—by an extravasation of blood, for example. Traumatic separation of the periosteum laying bare the bone does not of itself lead to necrosis, but the latter will develop if the bone becomes dry from long contact with the air, or if suppuration takes place.

Anatomical Changes in Necrosis; Separation of the Sequestrum (Demarcation).—When a portion of a bone has perished it is gradually separated or set free from the surrounding living bone by a demarcating inflammation. The separation of the dead bone—the demarcation, as it is called—is designated anatomically as a granulating, rarefying ostitis, the bone disappearing by lacunar absorption (see Fig. 401) along the line of demarcation. The piece of bone, after it has become completely separated, is called a sequestrum (Fig. 417, *S*). The outer, periosteal, cor-

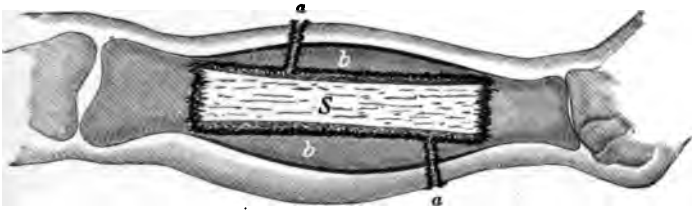


FIG. 417.—Complete necrosis of the diaphysis of the tibia: *S*, sequestrum; *a a*, fistulæ (cloacæ); *b*, newly formed bone or involucrum (schematic).

tical surface of the sequestrum ordinarily remains smooth, while the other portions of the sequestrum, where it is gradually set free from the living bone by the demarcation, appear rough and uneven, just like the ivory pegs which have been driven into a bone for pseudarthrosis (see Fig. 412). The size of every sequestrum is rendered less by this corrosion or abrasion, and, in fact, small sequestra, like small splinters of bone in fractures, may be completely absorbed if there is no suppuration and the granulating germinal tissue surrounds them closely. As is the case in the corrosion of the ivory pegs, so also in the separation of the sequestra and the absorption of small sequestra it is mainly the carbonic acid, resulting from the metabolism of the tissues, which in the free state, together with the osteoclasts, dissolves the lime salts. The length of time occupied by the process of demarcation till the sequestrum has been completely separated varies greatly, and depends upon the size of the sequestrum and its location. The activity of the separating process in different individuals is also very variable. In general it may be said that in extensive necrosis, such as the total necrosis of a diaphysis, the sequestrum requires in some in-

stances from three to five months, and in others from eight to ten twelve months, before it is completely separated. Separation tak place more rapidly in young than in old patients.

Hand in hand with the separation of the dead portion of bone i regeneration proceeds by reactive bone formation—i. e., by an ossifyin periostitis and osteomyelitis—as in the repair of fractures. Throug the action of the periosteum a capsule of bone—the involucrum, a it is called—is formed around the sequestrum, in the case of necrosi of the entire diaphysis (Fig. 417, *l* and Fig. 418, *b*). The fistulæ whic lead from the involucrum to th surface of the body are called cloa cæ, an expression which has passe out of use at the present time Through these cloacæ, or, better fistulæ, the pus escapes from th cavity containing the sequestrum (Fig. 417, *a*, and Fig. 418, *a*) Large defects develop especially i those parts of the involucrum wher the periosteum has perished in consequence of suppuration or a trau matism. In cases of central necrosis—i. e., necrosis in the interior of bone—the innermost layers of the involucrum are, of course, forme from portions of the old intact bone. But even in these centra necroses there usually occurs a reactive ossifying periostitis with th formation of fresh layers of bone. The capabilities of regeneratio possessed by bone (a subject which has been thoroughly investigate by Ollier) are in general very great, and a necrosis which involves th whole of a long bone can be so completely compensated for that n variations from the normal will be noticed. But occasionally the re generation is defective, or may even be entirely absent and permit the defect to persist. Not infrequently, in the case of a necrosis involving the diaphysis of a long bone in a young subject, there will be observed, in consequence of the irritation of the epiphyseal cartilages, an increased longitudinal growth causing the bone in question to become two to three centimetres longer than the corresponding one on the sound side.

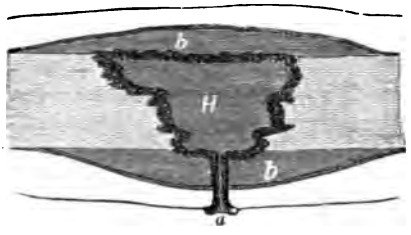


Fig. 418.—Partial necrosis of a hollow bone: *H*, cavity in the bone after removal of the sequestrum; *a*, fistula; *b*, newly formed bone or involucrum (schematic).

Various Kinds of Necrosis Distinguished by their Location and Extent —According to the situation and extent of the necrosis we recognise superficial, external, or peripheral necrosis in contradistinction to th above-mentioned central necrosis occurring in the interior of a bon We also recognise a partial and a total necrosis, and a multi

necrosis occurring in different portions of the same bone or in several bones of the same skeleton. The necrosis tubulata (Blasius) with a tubular-shaped sequestrum is very rare; the internal axis of the sequestrum is formed of living bone substance which is firmly connected with the old bone. Consequently we have to deal with tubular sequestra in which there is a preservation of the innermost layers of bone or a considerable regeneration of the latter by an ossifying periostitis.

Symptomatology and Diagnosis of Necrosis.—The symptoms caused by necrosis have already been partly described. They are mainly due to the demarcating inflammation and regenerative new formation of bone for casting off and replacing the dead portion, which come more and more into prominence after the subsidence of the primary disease (periostitis, osteomyelitis). If there has been a loss of substance in the overlying soft parts the dead bone will be plainly visible; but if the necrotic bone is covered by soft parts, and if the sequestrum is deeply situated, the bone will ordinarily be found to be evenly thickened at the affected point, as a result of the ossifying periostitis (Figs. 417, 418). The presence of fistulous tracts, which usually discharge only a little pus, is another symptom of necrosis of bone. If a metal probe is passed through these fistulous passages it will usually strike the surface of the sequestrum. The latter feels hard, and if percussed with the probe emits a tympanitic sound. In the case of superficial or total necrosis the surface of the sequestrum is smooth; if the necrosis is central the surface is rough. The dead bone is also recognisable by its lack of blood, and by its white colour when compared to the rosy appearance of the living bone. It is very important, both for diagnosis and treatment, to determine whether the sequestrum has become movable. The mobility of the sequestrum can be ascertained by pressing the probe firmly against it, or by passing two probes through two different fistulæ down to the sequestrum, or finally by attempting to move it back and forth by means of a dressing forceps. Occasionally a sequestrum which has become entirely free is so tightly enclosed that it is impossible to demonstrate its mobility. In such cases the separation of the sequestrum is determined by the duration of the disease. Necrosis may be mistaken for those central bone diseases which lead to enlargement of the bone with the formation of fistulæ, such as central bone abscesses and tumours of bone, and then particularly for caries. The typical caries, with few exceptions, as we saw, is a tubercular process, and is very often combined with necrosis. The tubercular sequestra usually contain cheesy tissue and have a soft feeling, while the sequestra of ordinary necrosis

appear white and hard, like normal bone. The pus in necrosis is scanty and more mucoid, but in caries it is a thin liquid mixed with cheesy masses. The fistulous tracts of tuberculosis generally have a pale, lardaceous appearance, and if a probe is introduced through them it strikes against soft, crumbling bone; while in necrosis the granulations usually have a vigorous, healthy appearance and bleed easily, and the sequestrum when touched by the probe feels hard. Furthermore, the development of the two diseases is different. The tubercular caries begins gradually, and mainly affects the epiphyses and the spongy bones, while the typical necrosis ordinarily develops after acute or subacute inflammation of bone, especially the long, hollow bones (femur, tibia, humerus).

Treatment of Necrosis.—The treatment of necrosis before the sequestrum has separated is purely symptomatic, and consists mainly in keeping the fistulæ clean. When the sequestrum has become completely free it must be removed by operation, if it has not already been spontaneously cast off or out. Even large, deeply located sequestra can work their way outwards through the cloacæ and come to lie beneath the skin, which they then gradually penetrate. I extracted simply with the fingers, in the case of a twelve-year-old boy, a large, completely separated sequestrum consisting of the entire thickness of the femur. During many months it had projected several centimetres from the soft parts, and no one had dared remove it. As a rule, only those sequestra which are completely free should be removed, but there are a few exceptions to this. In the case of phosphorus necrosis, for instance, the foul suppuration compels us to adopt operative measures before the sequestrum has become completely separated, and early resection—i. e., early removal of the primary focus of disease—should be undertaken to shorten the process and to prevent it from extending further. If the disease is left to itself, the entire lower jaw perishes, according to Häckel, in seventy-nine per cent. of the cases. In ordinary necrosis we must wait for the separation of the sequestrum to become complete, for the reason that the loss of substance will have been replaced by a new formation of bone, and that if we operate before the separation is complete we are liable to remove too much of the healthy bone, or possibly too little of that which is dead. In doubtful cases, where the mobility of the sequestrum cannot be determined, the length of time the process has lasted must be taken into consideration in deciding whether or not operative removal of the sequestrum should be undertaken. On the other hand, when the necrosis is extensive, though the sequestrum be free, the operation should be postponed if the new formation of bone is too scanty.

e **Operative Removal of the Sequestrum (Sequestrotomy).**—If the is is not encapsulated, the fistulæ are simply enlarged to the ary amount with the knife and the sequestrum extracted with e forceps, such as a dressing forceps. If the sequestrum is ulated by an involu- the latter must be l with the hammer and after freely dividing ft parts and elevating iosteum. An Esmarch ge should be used for tremities. After ex- n of the sequestrum ity in the bone should roughly scraped out, en either packed with m gauze, or the wound oft parts closed almost y by sutures, after pro- for drainage. If the is left to granulate, nning-over process can stened later on by nsplantation of skin. 's method of obtain- ling under an aseptic lot (see page 109) is od—i. e., the wound soft parts is closed res without drainage, I leave one angle open ans of escape for any accumulation of fluid. To prevent recurrences and to obtain recovery, the involucrum should be removed, as Riedel rightly ntil only a wall of cortex remains in the form of a flat gutter. operation has been performed with an Esmarch bandage, anti- lressings exerting pressure should be applied, and the extremity d, before the rubber tourniquet is removed; the limb should kept elevated for the next twelve to twenty-four hours. It is mportant that the extremity which has been operated upon be immobilised as much as possible by a splint. If fistulæ they must be thoroughly scraped out, and the sequestrotomy,

Fig. 419.—Incision *b*, *a*, *c*, *d*, for osteoplastic sequestrotomy.

Fig. 420.—Reflection of a flap of skin, periosteum, and bone in osteoplastic sequestrotomy.

when necessary, repeated for the extraction of any other sequestra which may be present. Sequestrotomy is not at all a dangerous operation if performed with antiseptic precautions.

Lücke and Bier have recommended a new method for sequestrotomy which is called osteoplastic necrotomy (Fig. 419). In the first place, the incisions *a c*, *a b*, and *c d* are made through the soft parts, then the bone, which in Fig. 419 is the tibia, is cut half through transversely with a keyhole saw and divided with the chisel in the line of the longitudinal incision. By depressing the handle of the chisel the skin-periosteal-bone flap thus fashioned is broken through along the line where it still remains joined to the rest of the cortex, and is turned back like the lid of a box, exposing the cavity containing the sequestrum (see Fig. 419). After removing the sequestrum and scraping out and disinfecting the cavity, the cover is replaced, and the wound in the soft parts closed immediately or by secondary sutures applied after the wound has first been packed. Recovery usually takes place with slight suppuration. In cases where after removal of the sequestrum a defect in the bone has resulted in consequence of incomplete formation of the involucrum, the defect is treated by the methods described on pages 607 and 629.

§ 107. **Spontaneous (Inflammatory) Separations of the Epiphyses.**—The spontaneous (inflammatory) separations of the epiphyses which occur in the bones of young subjects at the cartilaginous junctions with the diaphyses have already been discussed under the subject of Suppurative Periostitis and Osteomyelitis. As a matter of fact, the spontaneous separation of an epiphysis from the bone is almost always secondary to suppurative inflammation of the periosteum, the marrow of the bone, or the joint. But occasionally the epiphyseal separation is due to primary inflammation at the cartilaginous symphysis, as, for example, is the case in the osteochondritis luetica occurring in the course of syphilis. Multiple epiphyseal separations affecting several bones have been observed in pyæmia. The non-suppurative-spontaneous epiphyseal separation is very rare, and when it does take place may be due, according to Poupart, Petit, and Volkmann, to a hæmorrhagic malacia of the epiphyseal cartilages occurring in scurvy. The osteochondritis dissecans described by König, the nature of which is obscure, also sometimes leads to complete separation, for example, of the head of the femur from its neck, without any traumatism having been received, and even occurs in people from thirty to forty years of age.

According to Volkmann, the typical spontaneous separation of the epiphysis is generally observed before the fifteenth year, and no

case has been recorded where it happened later than the twentieth year. It is well known that the cartilage between the epiphyses and diaphyses persists till about the twentieth to twenty-second to twenty-fourth year of life, the epiphyses joining with the diaphyses somewhat earlier in women than in men. Separation of the epiphysis is most common at the lower end of the femur and the upper end of the tibia.

Traumatic separations of the epiphysis are described on pages 597 and 612.

The symptoms of epiphyseal separation are in the main those of a fracture, and repair takes place in precisely the same way. We have discussed on page 612 the occurrence of disturbances of growth after bony consolidation of the epiphyseal line. It need only be briefly stated here that in two cases of suppurative separation of the upper epiphysis of the tibia in comparatively young children, Blasius and Volkmann were able subsequently to demonstrate no shortening after the growth of the body had been completed.

The treatment of separations of the epiphyses is conducted according to the rules which govern the treatment of simple and compound fractures, and is the same as that for traumatic separations, which was given in § 101.

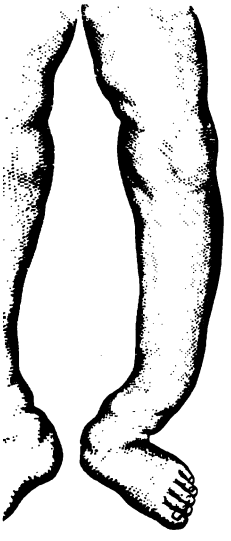
§ 108. **Rhachitis.**—Rhachitis (from *ῥάχις*, the spine) is a general disturbance of nutrition which occurs in early childhood, and anatomically is characterised mainly by the formation of bone which is deficient in lime, and by an increased absorption of bone. Therefore the bones affected by rickets are abnormally soft and have a tendency to bend, to suffer infractions; and the epiphyseal cartilages are remarkably thick—a peculiarity which has given the disease the name of *doppelte Glieder* (double limbs). Rhachitis is a disease affecting the development of bone, and a true disease of childhood, most commonly beginning in the first or second year of life, very rarely after the fifth or sixth. According to Schwartz, pronounced rickets is often observed in infants, and the investigations of Kassowitz show that it frequently begins during the latter months of fœtal life, in consequence of the transmission of morbid stimuli, or as a result of deficient absorption of lime from the maternal circulation, and then during the months immediately following birth the symptoms of the affection become more and more marked. Hereditary syphilis is, in my opinion, a predisposing factor in the etiology of rhachitis. In the Vienna obstetrical clinic, among five hundred children, Schwartz found 80.6 per cent. to be rhachitic, and the great majority of the mothers of these rhachitic children had lived under improper dietetic and hygienic conditions,

and during their pregnancy had done hard work. Marchand, Kaufmann, and others claim that a great many of the cases of so-called fœtal rhachitis are not real rickets. Marchand has accordingly proposed for these cases the name micromelia chondromalacia, and Kaufmann chondrodystrophia fœtalis. The fœtal cartilage is the site of the disease or malformation, and depending upon the condition of the same Kaufmann distinguishes (1) chondrodystrophia malacia, (2) chondrodystrophia hypoplastica, and (3) chondrodystrophia hyperplastica. The disease is sometimes hereditary. Infantile rhachitis is sometimes combined, particularly in the first years of life, with symptoms of scurvy, viz., hæmorrhages in the periosteum, the gums, the skin, the intestine, the bladder, mucous membranes, ventricles of the vein, etc. This affection (Barlow's or Möller's disease) is probably a specific cachexia.

FIG. 421.—Rhachitis. Longitudinal section through the upper epiphysis of the tibia near the boundary of ossification: *a*, zone of the proliferating columns of cartilage; *b*, vascular medullary spaces in the cartilage; *c*, calcified cartilaginous tissue; *d*, osteoid uncalcified or only slightly calcified tissue with remnants of cartilaginous tissue; *e*, fully formed bone.

Anatomical Changes in Rhachitis.—The anatomical changes in rickets have recently been studied by Virchow, Kassowitz, Baginsky, and others. Kassowitz ascribes all the manifestations of rhachitis to chronic inflammatory changes at the boundary line between the fœtal and infant bone—i. e., to an abnormally increased vascularisation of the tissues which go to form bone. As a result of this hyperæmia, and the numerous chiefly new-formed vessels at the epiphyses in the periosteum and medulla, there occurs a growth of the epiphyseal cartilages, a diminished deposit of lime salts, and an increased absorption of the fully formed bone. The bone undergoes a lacunar absorption (Fig. 401), osteoclasts being present, and, as I have stated before, is probably dissolved by carbonic acid. Rhachitic bone is poor in lime, and the newly formed bone remains for a long time in the uncalcified state. Not till the rhachitis has run its course does the ground substance of the bone become completely calcified, and then usually to an extreme degree, so that the affected bone appears thickened and very hard —sclerosed. The changes at the epiphyses are very characteristic. Under normal conditions the epiphysis is defined by a plain white line, cartilage

›eing sharply differentiated from one another. But in rhachitis
ɣ defined linear boundary is absent, and the different tissues, the
one, and medulla, appear as though blended together without any
;. 421). The cartilaginous epiphyseal line is broadened and irregu-
ındary between cartilage, bone, and medullary tissue is not well
d the zone of calcification at the points of ossification is absent or
The most important factors in the process are always the insuf-
›sit of lime salts and the increased absorption of the bone already
Baginsky states that rhachitic bone has lost more than three
the lime it contains. Rhachitic bones are so soft that they can
ıt with a knife, and, in consequence of this softness, deformities
›ton occur. In older children
s in the thorax, the vertebræ,
ities are more prominent than
ıe skull. Bow-shaped curves



hachitic deformities of the leg.

FIG. 423.—Bilateral rhachitic genu valgum in a boy five and a half years old cured by osteotomy of the femur and tibia.

the bones of the extremities, or, more commonly, angular deformi-
›nds of the diaphyses (Fig. 422) with thickening of the epiphyses.
are loose, abnormally movable, and painful. At the knee joint,
e, there is very often a considerable abduction or adduction and
the leg in consequence of the relaxation of the ligaments of the
he rhachitic curvature which exists in the tibia and femur (genu
l genu varum rhachiticum). At the hip joint the rhachitic bend-
neck of the femur is to be noted. In the foot the so-called "flat
ops, etc. This relaxation of the joints and softness of the bones
›ons why rhachitic children take so long to stand and walk, and
›se their ability to perform these acts in recurrent rhachitis or

rhachitis of late development. The pelvic walls sink inward, causing the cavity to become contracted, the promontory of the sacrum projects downwards and forwards, the acetabular region is pushed inwards, the symphysis forwards. Curvatures develop in the vertebræ (scoliosis, kyphosis), and the thorax, particularly at the points where the ribs join the costal cartilages, becomes depressed, so that in severe cases the sternum is pushed forwards (the so-called "chicken breast," or pectus carinatum). In the skull, especially in the occipital region, the bones remain for a very long time soft and yielding to pressure, and, as a result of the loss of bone substance, some portions may again become membranous (cranio-tabes rhachitica). The cutting of the teeth is delayed, and after the disease has been cured they often come through precipitately. The longitudinal growth and body weight are less than they normally should be. Bouchat states that rhachitic children only grow about two to three centimetres in a year, while the average longitudinal growth in health amounts to about seven to eight centimetres.

Among anomalies of internal organs are to be mentioned disturbances of the central nervous system and of the circulatory and digestive organs, such as, for example, hypertrophy or sclerosis of the brain, and chronic hydrocephalus. The spasm of the glottis, which is so common in rhachitic children, is probably caused by a general or a reflex anæmia. Disturbances of digestion (dyspepsia, diarrhœa alternating with constipation), chronic bronchitis, lobular pneumonia, etc., are very common. The liver is very often decreased in size; the spleen, on the other hand, is usually but not always enlarged, and sometimes attains enormous dimensions. The skin, mucous membranes, lymph glands, etc., often show the same disturbances of nutrition as in scrofula (see page 433). In the form of rhachitis appearing somewhat later in life (rhachitis tarda), Levrat (Lyon) very often observed goitre.

Analyses of the urine show, according to Baginsky, that (1) a healthy child retains more nitrogen in its system than a rhachitic one, and excretes phosphoric acid more freely in the urine; (2) that under the influence of dyspeptic conditions the rhachitic child excretes nitrogen in the urine more readily than the healthy child, and retains phosphoric acid; (3) that no difference can be made out between healthy and rhachitic children as regards the excretion in the urine of lime and magnesium; (4) that the relative amount of chlorine excreted in the urine of healthy children is greater than in that of rhachitic children. As regards the excretion of phosphorus or phosphoric acid in the urine of rhachitic children, the statements of authorities vary greatly; but as a general thing the majority of German authorities declare that there is a diminution of the phosphoric acid in the urine (hypophosphouria) in rickets; while the majority of French authorities maintain that there is an increase (hyperphosphouria).

The analysis of the ash of the fæces shows that more lime is excreted in the stools of rhachitic children (to one kilogramme of body weight) than is normally the case, and that the excretion of phosphoric acid, as compared with that in health, is not increased. The careful investigations of Babeau show that an abnormal amount of lime is excreted only in the developmental period of rickets; this occurs through the urine in case of imperfect assimilation of the lime in the bone, or through the fæces in consequence of insufficient absorption of lime by the intestine.

The Etiology of Rhachitis.—The cause of rickets—which we have learned to recognise as a general disturbance of nutrition in children, mainly localised in the bony system—has been made the subject of much experimental investigation. The majority of the authorities ascribe the cause of rhachitis to malnutrition. As a matter of fact, we know that a proper supply of the salts of the alkalies and of the earthy salts is of the greatest importance for the nutrition of all the tissues. Chossat and others have demonstrated by experiments on young growing animals that by feeding them with food deficient in lime, young birds and dogs, for example, show changes which are analogous to those in rhachitis; but the diminished absorption of lime should not be so much emphasized as the general insufficient nourishment and care of the child. Baginsky, whose careful investigations include 627 cases of rickets (347 boys and 280 girls), also states that the disease is a result of unfavourable conditions of life, especially deficient nourishment, bad dwellings, etc. Rhachitis is, in fact, a disease of the poor, particularly in large cities, and occurs less often in the country, as Morgan and Baxter have recently proved by extensive statistics. Billroth and Winiwarter maintain that in Vienna about eighty per cent. of the children of the poorer classes show symptoms of rickets. Children who are brought up by bad artificial feeding without being nursed at the breast, and who have disorders of digestion, are particularly apt to be affected with rickets. According to R. L. Lee, preceding respiratory disturbances due to bronchitis, pneumonia, whooping-cough, etc., are also of great etiological importance. Furthermore, we saw on page 663 that the syphilitic poison, and possibly also other hæmatogenous dyscrasiæ, excite changes at the epiphyseal junctions which are similar to those of true rhachitis; and doubtless rickety children suffer from hereditary syphilis more often than is generally supposed. Rickets is perhaps mainly an infectious disease; the poisons prevent a sufficient and permanent union of the lime salts with the tissue from which bone is formed.

The Course of Rhachitis is for the most part chronic, more rarely acute, and the earlier the rhachitis occurs the more rapid, as a general thing, is its course. Thus the rare cases of congenital rickets run a very rapid course; and of the children affected by the disease during the months immediately following birth, a large part perish from increasing inanition due to unfavourable hygienic conditions. But if the causative factors are removed, and the children properly fed and their surroundings improved, the disease usually disappears rapidly—in the milder cases within five to six months, and in the more severe ones within two to three years. Occasionally the disease drags on till

the fifth or sixth year; cases lasting longer than this are very rare. In the cases of *acute* rhachitis there are sometimes complicating disturbances of nutrition, particularly scurvy, which may occur simultaneously with the rickets (Th. Smith, Barlow, etc.).

The Diagnosis of Rhachitis, as a rule, is very easy, for the reason that the above-described anatomical changes in the skeleton are pathognomonic. It should be a rule, in making an examination, to undress completely all children suffering from chronic disease.

The Prognosis, if proper treatment is adopted, is favourable, as we have said before. But if the unfavourable conditions continue, a large proportion of rhachitic children perish from diseases of the intestinal tract, of the respiratory organs, from hydrocephalus, general inanition, etc.

The Treatment of Rhachitis consists, in the first place, in the administration of proper food to the child, and in doing away as soon as possible with all unfavourable hygienic conditions. Inasmuch as recent investigations show that rhachitis is of such common occurrence in young infants, they must always be carefully examined for its presence, and in cases where the disease is found the proper treatment must be begun early. The best food for suckling children is mothers' milk or good cows' milk sterilised by Soxhlet's apparatus. Nursing the child longer than the first year of its life, Baginsky states, is just as apt to cause rickets as is the administration at too early a period of starchy or indigestible food. All disorders of digestion and other complications in rhachitic children should be carefully treated according to the general rules which apply to them. Internally, cod-liver oil, iron, lime, phosphorus, arsenic, and pyrogallic acid have been recommended for rhachitis, but in their administration the state of the digestive organs must be taken into consideration. Cod-liver oil, which may be combined with extract of malt, is useful for children who are not fat, especially in winter. Lime is given in the form of liquor calcis added to milk, or in a mixture made of carbonate and phosphate of calcium with ferri oxyd. sacch. (ferri carb. sacch.), equal parts of each, enough to cover the point of a knife, three times a day. On account of its osteoplastic action the administration of phosphorus has recently been recommended for rhachitis by Wegner and Kassowitz. It is given (1 milligramme *pro die*) in cod-liver oil (0.01 gramme phosphor., 1000 cubic centimetres ol. morrhuæ, one to two teaspoonfuls a day), or in pill form with oil of phosphorus and some indifferent powder enclosed in gelatine capsules. Maas and others maintain that arsenic and pyrogallic acid have also an osteoplastic action like phosphorus. Three per cent. brine baths, sea baths, health resorts situated on high land, and proper climate have as valuable an influence upon rickets as they have

upon scrofula (see page 434). To prevent as far as possible the curvatures and angular deformities which may occur in the extremities, for example, rhachitic children should not be encouraged to stand and walk at too early a period. Braces and similar apparatus should be used to support the lower extremities, and the application of light water-glass or starch dressings is also advantageous. After the rhachitis has subsided, the bony deformities, particularly those in the leg, frequently have to be corrected. Rhachitic curvatures often straighten out spontaneously, and hence one should not operate too soon. Up to the fifth year they can usually be treated expectantly; after that they generally have to be corrected by osteoclasis (see page 91), or, better, by osteotomy. To perform osteotomy, the proper incision is made through the skin, and through this the bone is divided with the hammer and chisel, with the exception of a small portion of the cortex, which is then usually broken by hand. The wound is not sutured, and after covering it with an antiseptic protective dressing a plaster-of-Paris splint is immediately applied. If the operation is carried out with antiseptic precautions it is entirely devoid of danger. Macewen's osteotomy at the lower end of the diaphysis of the femur is also very appropriate in cases of genu valgum rhachiticum. Tenotomy of the tendo Achillis must sometimes be added when the curvature of the tibia is convex anteriorly. But frequently braces will be sufficient to overcome deformity, the bones gradually becoming straight of their own accord. I must refer the reader to the Regional Surgery for the particulars of the treatment for the various sequelæ of rhachitis in the different portions of the body, such as the vertebræ, the extremities, etc.

§ 109. **Osteomalacia.**—By osteomalacia we understand a peculiar softening and absorption of bone substance which is observed most commonly in women during pregnancy and the puerperium, less often in men, and in women who are not pregnant. The disease not infrequently occurs in pregnant and milch cows. In osteomalacia the normal, strong bones of adults become soft, while in rhachitis, on the other hand, we have to deal with a disease of development affecting young bone, in consequence of which the latter remain soft and do not become firm.

Anatomical Changes in Osteomalacia.—The puerperal form of osteomalacia probably always begins in the pelvis, and either remains limited to the latter or attacks other bones, and may even involve most of the skeleton, particularly if the woman passes through several pregnancies after the appearance of the disease. The non-puerperal form begins most commonly in the vertebræ and thorax, and then extends to the extremities, and finally to the bones of the head. The softening, the absorption of bone substance (Fig. 424), is an halisteresis—i. e., the lime salts are first dissolved, but the

decalcified ground substance persists a little while longer, then it also gradually disintegrates, and is finally absorbed. The absorption of the lime salts always begins in the periphery of the bone and advances steadily towards the centre. In this manner a considerable loss of bone may be brought about and the cortex of the long bones may become as thin as paper, or the diseased bone may even entirely disappear, leaving only the periosteum and medulla to persist as an elastic tube. Morand observed a very pronounced degree of osteomalacia in a woman who possessed in the place of most of her bones only membranous cylinders or very thin tubes of bone. In the milder cases, which recover quickly, the decalcified bone substance can be very rapidly changed to normal bone by a fresh deposit of the salts of lime. As long as the disease is advancing the medulla is usually very richly supplied with blood, contains numerous hæmorrhagic foci scattered through it,

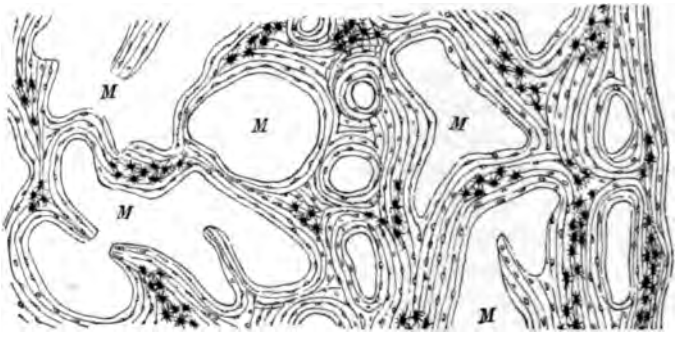


FIG. 424.—Osteomalacia (pelvis). Trabeculæ of decalcified bone with remnants of calcified bone. The enlarged medullary spaces (*M*) have arisen from absorption of the trabeculæ. x 75.

has an abundance of cells, and is poor in fat. In rare instances of osteomalacic softening of bone there have been noted multiple cystic formations with tumour-like enlargement of the softened portions of bone (Albertin). There are, moreover, cases which present the clinical picture of osteomalacia, and anatomically are due to the development of multiple true tumours, especially sarcomata (Recklinghausen). As a result of the softening of the bones there of course arise corresponding curved or angular deformities and fractures. Changes of shape in the osteomalacic pelvis are particularly common. Recklinghausen and Rehn have recently described an infantile osteomalacia, but this is probably in the main a severe rhachitis.

The Etiology of Osteomalacia.—The precise cause of osteomalacia is still but little understood, though various theories have been advanced. We only know that it occurs chiefly in pregnant or nursing women and animals, and is common in certain regions which in Germany lie along the Rhine, while other places, like the valley of the Oder, appear to be free from it. Damp, unhealthy dwellings, malaria, anæmia, and other constitutional anomalies connected with disturbances of nutrition, are said to be of importance. Cohnheim maintains that osteomalacia,

like rhachitis, is a disturbance of nutrition, and he believes that the maternal organism during pregnancy and the nursing period contains too little lime, because a very large amount of lime salts is necessary for the development of the fœtal skeleton as well as for the milk. For this reason only osteoid tissue, which is deficient or entirely lacking in lime, is formed in the maternal organism. Consequently, according to Cohnheim's theory, the uncalcified or deficiently calcified bone tissue is not decalcified *old* bone tissue, but new-formed osteoid tissue. I believe, however, that the old idea is correct, viz., that the bone tissue which is poor in lime or in which the lime is absent is the decalcified ground substance of the old bone. It is natural that the cause for the decalcification in this condition should also be ascribed to an acid such as lactic acid, or, more correctly, carbonic acid; but as yet no proof of this has been obtained. Heiss and others have fed animals with lactic acid for months (three hundred and eight days, for example), and yet have not been able to produce osteomalacia. It seems more probable that the decalcification is due to the action of carbonic acid; it is possible, and the hyperæmia of the medulla favours this view, that in osteomalacia we have to deal with an inflammatory process accompanied by an increased vascularity and an abnormal formation of carbonic acid. Examination of the urine, however, does not always show an increased excretion of earthy phosphates, a thing which the acid theory would lead us to expect. On account of the success obtained in the treatment of the disease by removal of the ovaries, Fehling holds the opinion that it is caused by a pathological hyperactivity of the ovaries. In consequence of the reflex dilatation of the vessels in the bone there is a passive hyperæmia, and later an absorption of the bone. Petrone calls attention to the increased amount of nitric acid contained in the urine, and believes that osteomalacia is caused by the micro-organism described by Schlössing and Münz, which produces nitric acid. In one case of non-puerperal osteomalacia observed by Kobler, with pronounced changes in almost all the bones, examination of the ash obtained from the blood revealed a considerable increase of sulphuric acid and a diminution of the sodium to less than half the normal quantity. The rare osteomalacia of men, and of women who are not pregnant or nursing, depends, according to Cohnheim, in the main upon disorders of digestion or of assimilation, combined with a lessened absorption of lime.

We have practically given the symptomatology of osteomalacia in the above description. The disease almost always begins, as we have said, during pregnancy or during the puerperium, with severe shooting pains in the affected bones. Consequently the disease, at the outset,

is often confused with rheumatism, until the changes in the shape of the bones enable the correct diagnosis to be made. The affection may become very pronounced during a single pregnancy or a single puerperium. The milder cases will get entirely well; but very frequently the disease makes pauses in its progress, and then, in conjunction with another pregnancy, though apparently cured, it will break out again with fresh intensity. Recklinghausen observed osteomalacia in young subjects in combination with Basedow's disease.

The *prognosis* of osteomalacia is very unfavourable, and actual cures are exceedingly rare. Nevertheless, the operative removal of the ovaries in puerperal osteomalacia, recently recommended by Fehling, yields surprisingly good results.

The *treatment* of osteomalacia is like that of rickets (see pages 668, 669), and consists primarily in the administration of good nutritious food, also cod-liver oil, iron, lime, quinine, phosphorus, and arsenic. All unfavourable hygienic conditions, disturbances of nutrition, and constitutional anomalies are, as far as possible, to be done away with. If the woman is nursing her child, she must be forbidden to do so, and made aware of the danger that in a new pregnancy the disease may recur with increased severity. Great interest attaches to the cures of osteomalacia recently obtained by the removal of the ovaries. The observation has been made that after removal of the uterus pregnant women suffering from osteomalacia were cured, and hence Fehling recommended simple castration for the same purpose. The success of this procedure is so marked that patients with a very severe form of the disease can be cured and allowed to attend to their employment after the lapse of from three to four to five weeks. Petrone believes that the success is mainly to be ascribed to the narcosis, and not to the operation, as he has cured one case of osteomalacia in three weeks by the daily administration of two grammes of chloral hydrate, the nitric acid which was present in the urine disappearing on the fifth day of the treatment.

The castration recommended by Fehling for osteomalacia, with or without supravaginal removal of the uterus, deserves the most general consideration because of the success which has already been obtained. Kummer collected in 1891 thirty-eight successful cases of double castration for osteomalacia. In cases of pregnant women the uterus will usually be removed as well. We must not omit to state that in rare instances the osteomalacia of women also gets well spontaneously.

§ 110. **Atrophy and Hypertrophy of Bone.**—Atrophy of bone is due to various causes. Every absorption of fully formed bone substance, which, as we have seen, occurs so frequently under pathological condi-

is, is to be looked upon as an atrophy of bone. The absorption of e substance either takes place on the external surface of the bone or tarts in the medulla and advances outward. In the outer (concen- atrophy the bone becomes smaller and thinner, while in the case he internal (excentric) atrophy the medullary cavity and the Haver- canals grow larger and the bone becomes porous (osteoporosis).

ophy of bone is sometimes congenital; plete defects—e. g., of the radius, ulna, la, or tibia—occasionally occur and cause esponding deformities of the hand and . The bone in question has in all proba- y been made to disappear through con- tion by amniotic threads, folds, or strands. presence of cicatrices and the combina- of defects in the bone, with intra-uterine utations, point to this etiology.

Fig. 425.—Partial (trophoneurotic?) atrophy of the skeleton (upper part of the body); pelvis and lower extremities are well-developed; thirty-five-year-old unmarried woman (Mosengeil).

The *senile atrophy* which affects the bones he skull (the cranial vault, the inferior illa, etc.) and of the extremities, especially r articular ends, is a special form of bone phy. The senile osteoporosis of the neck he femur is of practical importance, as the t gradually becomes depressed and may roken by a very slight traumatism.

A common cause of the atrophy of a e is disuse of the latter (atrophy of dis- . We have said that this follows paral- , inflammations of joints, temporary im- ilisation of an extremity by a plaster-of- is dressing, etc. The disappearance of acetabulum, which occurs when a disloca- of the hip is not reduced, also belongs to atrophies of disuse. This form of atrophy take place in certain limited portions of ne, as in the callus formed after a frac- , those portions of the bone substance lually disappearing which have become useless for the function he bone.

Another form of atrophy of bone is the neuroparalytic and trophotic, which occurs in conjunction with diseases of the nervous em, such as tabes, or as a result of changes in the trophic nerve es or afferent nerves, or in the trophic centres in the anterior

horns of grey matter in the spinal cord (Fig. 425). Division of the sciatic nerve in animals has been found to cause lengthening and thickening of the bone, sometimes with an increase in weight and sometimes a diminution in weight and great pliability and fragility of the bone. A detailed description of the trophoneurotic diseases of the bones and joints is given in § 117.

Fig. 426.—Partial giant growth on the hand (Curling and Böhm).

Local arrest of longitudinal growth is caused by diseases of the epiphyseal cartilages, such as inflammation or suppuration, or it may follow their ossification at too early a period or their removal in too extensive a resection, etc. Pressure, inflammation, and the development of a tumour may also lead to localised atrophy, to wearing away of bone, or to caries.

Hypertrophy of Bone is either limited to some particular portion of a bone, as in the formation of osteophytes, or it affects the entire bone, the whole volume of the latter being increased or only its length or thickness. The hypertrophies include the hyperostoses mentioned on a previous page—i. e., the increase in volume following periosteal and endosteal formation of bone, and the *osteosclerosis* or thickening of bone tissue, which is also called eburneatio ossis.

Fig. 427.—Giant growth of the upper extremity and the right side of the thorax (Wagner).

Leontiasis Ossea.—Hypertrophy of the facial and cranial bones is of special interest, the so-called leontiasis ossea, the etiology of which is very obscure. There is probably a congenital predisposition. The affection occurs usually in young individuals of both sexes who are otherwise healthy, and begins as a painless, increasing enlargement of the malar bone; the hypertrophy then gradually attacks, as a rule, almost all the bones of the face and skull symmetrically. The newly-formed bone, which is at first spongy, becomes increasingly harder. There is a constant increase in the size and weight of the bones. The sense of smell and of sight are lost, and after a number of years (ten to

thirty) death occurs, sometimes from increasing cerebral compression. The other bones remain healthy. No treatment has been found of any avail.

Helferich and others have, as we remarked before, increased the development of bone at a given point by artificial hyperæmia, produced, for example, by tying off the extremity with an elastic tourniquet drawn moderately tight on the proximal side of the point in the bone which is diseased. This procedure is worth trying in the case of fractures where the callus formation is delayed and insufficient, and in pseudarthrosis, and also to diminish shortening, etc. (see page 603).

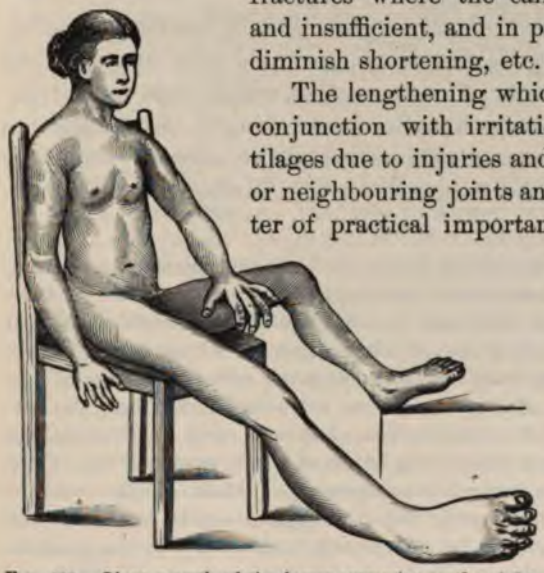


Fig. 428.—Giant growth of the lower extremity on the right side and the upper extremity on the left side.

The lengthening which bones may undergo in conjunction with irritation of the epiphyseal cartilages due to injuries and diseases of the diaphysis or neighbouring joints and soft parts, is also a matter of practical importance. As Ollier has demonstrated experimentally, an increase in the longitudinal growth of young bones is very easily brought about by stimuli of various kinds. This explains the occurrence of the increased longitudinal growth which takes place in conjunction with fractures, especially those which are compound and heal with marked inflammatory reaction, or which follows necrosis, osteomyelitis, large ulcers of the foot, and diseases of joints. Young bones which have been dislocated and not replaced take on increased longitudinal growth if they are freed from the pressure of the superimposed bone. Thus, for example, increased longitudinal growth of the radius takes place after dislocation of its head.

Congenital hypertrophy of bone makes its appearance in the form of *giant growth* of the fingers and toes (Fig. 426, macrodactylia), and also as giant growth of an entire extremity (Figs. 427, 428). According to Wittelshofer's statistics, all the cases of true giant growth hitherto recorded are congenital in origin, and originate, as in the case of the very considerable monstrosity illustrated in Figs. 427 and 428, from an abnormal increase of growth involving all the tissues of one part of

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the body. Giant growth is possibly a congenital trophoneurotic disturbance.

The cases of *acquired* hypertrophy of the bones and soft parts (compensatory hypertrophy) are, of course, to be distinguished from this congenital giant growth. P. Wagner has recently collected several cases of congenital and acquired giant growth, and has given the literature on this subject (Zeitschrift für Chir., Bd. xxvi, S. 216). Bessel-Hagen has called attention to the various anomalies of the bones and joints which occur in giant growth.

As regards the *treatment* of partial giant growth, elastic bandaging, massage, and Weir Mitchell's cure have been used with success in the milder forms of the affection. In severe cases, which cause much trouble in consequence of the awkwardness and weight of the affected extremity, operative measures will sometimes be necessary, and the enlarged member should be removed (see also Treatment of Elephantiasis).

Acromegaly, a disease to which Marie, in 1886, first directed attention, must be carefully distinguished from the congenital giant growth. In acromegaly, which begins about the tenth to the twentieth to the thirtieth year of life, and lasts ten to twenty years or longer, there is a hypertrophy of all parts of the body, involving both the bones and the soft parts, especially of the head and extremities. Multiple exostoses are sometimes found, particularly on the long bones of the extremities. In some cases an abnormal increase in height takes place after completion of the normal growth of the body. The hands and feet have the appearance of paws. In the head the hypertrophy affects most commonly the lower jaw, tongue, under lip, and nose. The power of vision may be completely lost, owing to the pressure exerted by the enlarged sphenoid bone on the optic nerve. Hadden and Ballame state that the disturbance of sight is caused by compression of the optic chiasm or medullary striæ of the optic nerve brought about by the hypertrophy of the pituitary body. The vertebræ, sternum, and ribs are symmetrically enlarged; there are kyphotic curvatures of the spinal column; the joints are deformed; the internal organs, brain, muscles, nerves, etc., hypertrophy. Atrophy of the thyroid gland was present in some of the cases, and in place of hypertrophy or tumour formation of the pituitary body there was degeneration of the same. In consequence of thickening of the epiglottis, the laryngeal cartilage, and the vocal cords, respiration may be very much interfered with, so that death may take place suddenly from œdema of the glottis. The subjective symptoms presented are pains in the head and joints, a feeling of weakness, and paræsthesia. A steadily increasing cachexia finally makes its appearance. The precise cause of acromegaly is still obscure. According to W. A. Freund, the affection is an anomaly of growth, and he believes that its immediate cause must be ascribed to an increased flow of blood to the dilated vessels. As opposed to this anomaly of the vessels others lay stress upon the neurotic origin of the disease—e. g., as the result of central or peripheral nervous disturbances. Inherited predis-

position to the disease is contested by some authorities and accepted by others. It probably has a complex etiology, and occurs after various kinds of disorders. Great psychical excitement has frequently been thought to be the exciting cause of the affection.

Acromicria.—The condition the reverse of acromegaly is called acromicria (Stembo, Reidel). In this there is a striking atrophy, especially of the terminal portions of the body (head, fingers, toes), together with a process of shrinkage, which attacks different organs and sometimes the entire body. The etiology of the affection is very obscure, and the disease must be carefully differentiated from syringomyelia, Morvan's disease, the anæsthetic form of leprosy, Raynaud's disease, and from analogous syphilitic or diabetic affections of the fingers. According to Stembo, the disease begins on the fingers. On the latter there is often a development of blebs or ulcers, which heal slowly, and are accompanied by intermittent pain. The skin on the fingers grows more and more thin, cicatricial, and tense; all the nails perish, the fingers become shorter and less movable, and the entire body grows smaller, from atrophy of the skin and the soft parts, including the tongue and œsophagus. The face assumes a peculiar stiff, immovable, and bird-like expression. There are no disturbances of sensibility, the cutaneous reflexes are normal, the tendon reflexes diminished, and the electrical excitability of the muscles and nerves is slightly increased.

Daily Variations in Height.—As regards the well-known fact that man becomes shorter in the course of the day, Merkel has made some accurate measurements (mostly upon himself), and has found that the length of the body in the morning in the recumbent position, immediately after awakening, is some five centimetres more than in the evening in the erect position. The loss in size is partly gradual and partly sudden. The former is due to the gradually increasing compression of the sole of the foot and the intervertebral fibro-cartilages; while the latter, or sudden diminution of stature on rising from the horizontal to the perpendicular position, is brought about by compression of the joints of the lower extremity, a shortening of eight millimetres taking place in the region of the ankle joint, of two to three millimetres at the knee, and of one centimetre at the hip. This lessening of the length of the lower extremities is mainly caused by compression of the elastic articular cartilages and by the sinking of the caput femoris into the cavity of the acetabulum, which occurs upon standing in the erect position.

Lymphadenia Ossium (Nothnagel).—A peculiar kind of pernicious bone disease, which has been described by Nothnagel, requires mention at this point. It was observed in a man twenty-four years of age, and terminated fatally in a year and a half, the patient having been afflicted with severe pains, thickening of the bones, and steadily increasing cachexia. The autopsy revealed a very extensive development of a lymphadenoid tissue, with a great number of Charcot-Neumann crystals in the bones, and at the same time a periosteal and medullary new formation of bone. The medulla had almost completely disappeared. Nearly all the bones were diseased, the phalanges of the hands and feet and the bones of the face alone remaining unaffected. The lymph glands and the spleen were enlarged, probably to compensate for the lack of medullary tissue, with its power of making blood.

§ 111. **The Tumours of Bone.**—The tumours peculiar to bone (osteoma, exostosis, osteosarcoma, enchondroma, soft-bone tumours, cyst, etc.) will be described in §§ 125–130, where we shall take up the subject of tumours in general. At present we shall only briefly discuss the parasitic tumours of bone.

Of animal parasites there occur in bone the *echinococcus* and the *Cysticercus cellulosæ*, the latter being very rarely met with. Volkmann mentions one case of Froriep's, in which this parasite was found in the first phalanx of the middle finger, the symptoms being those of a suppurative periostitis.

Of echinococcus of bone there are fifty known cases.

FIG. 429.—Echinococcus of the femur and tibia of a fifty-two-year-old woman: *a*, large echinococcus cyst. Amputatio femoris (Hahn).

Echinococcus of Bone.—The tænia echinococcus, as is well known, is a four-jointed parasite about four millimetres long, which lives in the intestinal canal of the dog; and only the cysticercus of this tænia, after the introduction of the tænia eggs into the intestinal canal, occurs in man. In whatever organs the embryo lodges, the liver being the one most commonly affected, characteristic cystic tumours develop. The cyst is made up of a lamellar, very elastic cuticular layer (ectocyst), on the inner surface of which is a granular parenchymatous layer. From this inner layer the so-called brood-capsules develop, and upon these are formed the scolices in great numbers. The echinococcus cyst either remains single—unilocular—or it goes on to form daughter cysts by exogenous and endogenous proliferation. The size of the cysts, especially in the liver, is often very considerable. The echinococcus multilocularis is another form of the echinococcus, which forms in the liver only small cysts in great numbers, varying from the size of a millet grain to that of a pea, which are surrounded by a thick, tough, diffuse mass of connective tissue.

The echinococcus cysts excite a local inflammation which leads to the formation of a connective-tissue capsule. The cysts, after attaining the size of a walnut or apple, often die, and their fluid contents become absorbed, a cheesy, fatty detritus or calcification being then found inside the shrunken sac. In other instances the cysts grow so large as to become dangerous, and by penetrating or bursting into some cavity of the body give rise to severe inflammations. For a more detailed description of echinococcus, see Vol. III, § 161.

The echinococcus develops in bone, especially in the medulla (Fig. 429), and occasionally forms at some point where the bone has been sub-

ected to a traumatism. The echinococcus cysts of bone are of slow, ndolent growth, and after the lapse of years sometimes gives rise to ainful tumours, which at the outset present the appearance of a cen-ral bone tumour nd subsequently f a bone cyst. he affection oc-asionally remains atent for several ears. Echinococ-us cysts usually ary in size from hat of the head of pin to that of a ea, or they form arge cysts (Fig. 29, *a*) which commonly break through the cortex after they have xisted a long time, and invade the surrounding soft parts, muscles, essels, and nerves, or neighbouring joint (see page 680). As Bergmann as remarked, there is sometimes a formation of abscesses in the tissues round the bone, which after being incised show no tendency to heal, nd may lead one to suppose that there is a necrosis present. The us at times is remarkably rich in cholesterin crystals, a fact which is f importance for the diagnosis. The destruction of bone is not infre-uently very considerable (Fig. 430). The periosteum and medulla re usually passive, and hence the process does not ordinarily result in egenerative growth of the bone from the periosteum or medulla. It s worth noting that, as Gangolphe says, the multilocular form of chinococcus of bone is by far the most common ; it was found thirty-wo times in thirty-seven cases, and only in five instances was encysted chinococcus present (which is much the more common form in the oft parts, especially in the liver). Of fifty-two cases, twenty-six were f the hollow bones (eleven humerus, eight tibia, six femur, one pha-anx) and eighteen of the flat bones (eleven pelvis, four each involving he skull, scapula, and sternum, and the ribs once).

Fig. 430.—Echinococcus of the pelvic bones on the right side, with well-marked absorption of the bones of the pelvis and head of the femur in a twenty-five-year-old peasant woman (Viertel).

The *diagnosis* can only be made with certainty when the soft, fluctuat-ng tumours have broken through the bone, or when a portion of their con-nts can be withdrawn by an exploratory puncture. In the case of the long ollow bones the nature of the disease is occasionally revealed by the occur-nce of a spontaneous fracture.

The *prognosis* is governed by the location of the disease, echinococcus the bones of the skull and of the vertebræ and pelvis being the most nfavourable, while the echinococcus of the extremities is less so. Gan-

golphe states that out of seven cases of echinococcus of the vertebræ, six died of sepsis after the operation, while of nineteen patients with echinococcus of the extremities only four died.

The *treatment* consists in as complete a removal as possible of the cyst as well as of the diseased bone, or, when this cannot be done, in incision, with destruction of the membrane by means of the sharp spoon, Paquelin thermo-cautery, etc. In the case of the extremities, amputation or disarticulation will often be necessary. Of the thirty-six cases of echinococcus of bone collected by Reszey and Hahn, twenty were operated upon, and of these fourteen were cured (two by incision, twelve by amputation). At all events the treatment should be as energetic as possible so as to prevent recurrences.

Echinococcus in Joints.—Occasionally, as we have remarked before, an echinococcus of bone breaks through into the neighbouring joint (Fischer found ten such cases in literature); but it is extremely rare for the parasite to lodge primarily in the joints. Of the above-mentioned ten cases, eight affected the hip joint, one the knee, and one an interphalangeal joint. Of echinococcus cysts of the pelvic bones with perforation into the hip joint, only one case has been cured by operation (Bardeleben). The treatment of this affection of the joints demands very energetic procedures (resection, or even amputation).

CHAPTER IV.

INJURIES AND DISEASES OF JOINTS.

Review of the anatomy of joints.—The acute inflammations of joints: Acute serous, sero-fibrinous, and suppurative synovitis.—Acute polyarticular rheumatism.—The secondary inflammations of joints occurring in the course of acute infectious diseases (metastatic inflammations of joints).—Gonorrhœal arthritis.—The acute arthrites occurring in the course of syphilis.—Arthritis urica (gout).—Gout from lead poisoning.—Treatment of acute inflammations of joints.—The chronic inflammations of joints: Chronic hydarthros.—Chronic articular rheumatism.—Chronic suppuration of joints.—Fungous (tubercular) arthritis, joint caries.—Syphilitic arthritis.—Arthritis deformans.—Diseases of joints in bleeders (hæmophilia).—Joint bodies.—Articular neuralgias, articular neuroses (hysterical joint affections).—Neuropathic inflammations of bones and joints.—Anchyloses.—Deformities of joints (contractures).—Echinococcus of the joints (see page 680).—The injuries of joints: Subcutaneous injuries (contusions, sprains).—Dislocations (luxations) of joints.—Wounds of joints.—Appendix: Gunshot wounds.—Remarks upon military surgery.

§ 112. **Review of the Anatomy of the Joints.**—It is well known that the cavities of the joints of the cartilaginous skeleton of the fœtus are made by dehiscence, or softening and liquefaction of the formative tissue remaining between the cartilaginous layers. They develop later than the ligaments of the capsule, which, as processes of the perichondrium, stretch across the space lying between the ends of the cartilages. The articulations between the bones are commonly divided into two classes: the synarthroses and the diarthroses. The synarthroses are characterised by having a cartilaginous or fibrous layer interposed between the bone surfaces, which is connected to the periosteum, the latter extending from one bone to the other. In the diarthroses the continuity is completely interrupted, and they are provided with a loose capsule, which is generally strengthened by accessory ligaments. The inner surface of the capsule of a joint, or the so-called synovial membrane, is covered usually by a single layer of endothelium, which, as my investigations show, very often extends over the synovial fringes and interarticular ligaments as far as they lie free in the cavity of the joint, but under normal conditions does not, as a rule, cover the point

of origin of the synovial membrane at the articular cartilage. In fœtus the cartilage is ordinarily partially covered by endothelium, a after birth, if a joint remains quiet for any length of time, the en thelium will grow over p tions of the articular cartila and other parts of the jo which present free surfac As an individual increases age the endothelium of t synovial membrane becom modified at the places of grea est friction, and it is ofte completely absent here (Ha gen - Toru, Braun). On th inner surface of the synovia membrane there are foun thread - like outgrowths, th synovial villi (Figs. 431, 432) which can be seen especially well as floating structures when a joint like the knee is opened under water. Some of the villi contain vessels (Fig. 432), others do not; and some of them are single filaments, while others are branched and are provided with daughter

Fig. 431.—Synovial villi (knee-joint). Glycerin-osmic acid. × 30.

Fig. 432.—Vascular synovial villi. Five per cent. bichromate of potassium. Knee-joint of man. × 30.

i. According to the nature of the tissue, cartilage villi, fibrous i, fat villi, and mucous villi can be distinguished, while between

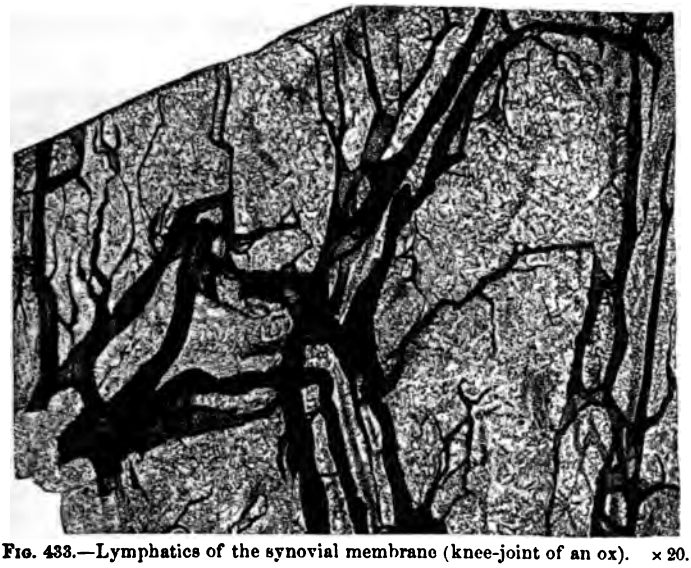

FIG. 433.—Lymphatics of the synovial membrane (knee-joint of an ox). × 20.

e individual kinds there are numerous transition forms. Cartilage are very often found in the fibrous villi.

The joint capsules are, as Fig. 433 shows, richly supplied with lymph vessels—a er of great practical importance. It is sup- d that there are open communications— ata, as they are called—between the lymph nels and the joint cavity on the inner sur- of the articular capsule, as there are in r serous membranes; but as yet I believe ne has been able to demonstrate them.

FIG. 434.—Hyaline cartilage treated in an incubator with trypsin. Network arrangement of the fibres. × 150.

The hyaline cartilage is only apparently ogeneous. As I was the first to show hiv für Anat. und Phys., 1877), it can be onstrated by means of trypsin, or the pro- ed action of permanganate of potassium, hyaline cartilage is really made up of fibres h are bound together by a cement sub- ce. The latter is dissolved by the above- tioned materials, especially by the action of trypsin at a tempera- of 38° to 40° C. (101.4° to 104° F.) in the incubating oven, and

the fibres are then made evident (Figs. 434, 435, 436). They may have a lamellar arrangement, as in Fig. 435, or form a network, a reticulated structure (Figs. 434, 436). Through our knowledge that even hyaline cartilage is constructed of fibres, we can more readily understand the various changes which occur, for example, in the calcification of the callus or in the repair of wounds

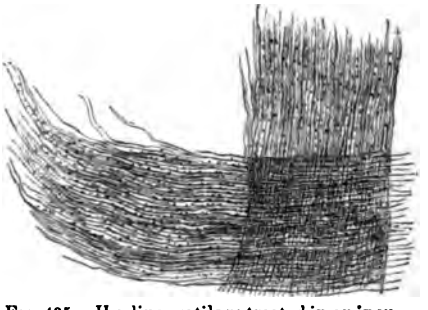

FIG. 435.—Hyaline cartilage treated in an incubator with trypsin. Arrangement of the fibres in the form of lamellæ. × 240.

FIG. 436.—Hyaline cartilage treated in a hatching oven with trypsin. Network arrangement of the fibres. × 240.

of cartilage, also the fibrillation of hyaline cartilage which takes place in chronic joint disease, etc. We have Budge to thank for his beautiful investigations upon the circulatory channels in cartilage.

The views of authorities vary as to the origin of the synovia, but my own investigations have led me to believe that it is mainly formed by the mucous and fat villi, partly by secretion and partly by a breaking up of their cellular elements. However, this is not the place to discuss any more fully the anatomy and physiology of joints, and I must refer the reader to the text-books on these subjects; but I have thought it wise to briefly touch upon some of the questions which are particularly important as regards the subject of diseases of joints. The mucous bursæ are described in § 99.

§ 113. **The Acute Inflammations of Joints.**—We distinguish, according to the nature of the exudate in the acute inflammations of joints, two main varieties: the *serous* and the *suppurative*.

1. The *acute serous synovitis* is usually characterised by the presence of a cloudy, serous liquid containing a greater or less number of fine flakes of fibrin. If there is a considerable quantity of the latter present the synovitis is also called sero-fibrinous. The other pathological changes which occur in a serous synovitis consist in a varying amount of hyperæmia and swelling, and upon microscopical examination there are usually found here and there small collections of leucocytes or extravasations of blood.

The *clinical course* of a serous synovitis is briefly as follows: If we suppose, for example, that the knee joint is the one affected, it is usually swollen and feels hot, is tender to the touch, and on palpation fluctuation is plainly made out, and the patella is lifted from its normal position—it "floats." Active and passive movements of the joint are possible, but cause pain. There is either no fever at all or only a very slight amount of it. The further course of the disease is in the main dependent upon the cause, but it is ordinarily favourable, and if proper treatment is adopted recovery will very speedily ensue. Occasionally an acute serous synovitis will change into the suppurative form or into a chronic hydarthros. Not infrequently after recovery from the acute hydarthros there is a pronounced tendency to relapses. Garré found as the cause of one case of recurrent synovitis of the ankle joint an encapsulated osteomyelitic focus in the internal malleolus. After this had been chiseled open and treated the synovitis did not recur. The pus in the osteomyelitic focus contained virulent staphylococci.

2. *Acute suppurative synovitis and arthritis* is characterised anatomically by the formation of a purulent or fibrino-purulent exudation. It either follows a serous or sero-fibrinous inflammation or begins as such. In addition to the pure or flocculent pus which is found in the joint, there is also usually present a marked swelling and hyperæmia of the synovial membrane and ligaments upon which a fibrino-purulent material is deposited, sometimes containing foci of pus. Furthermore, the articular cartilages become dull in appearance, and there is an even extension of the synovial membrane over their edges in the form of vascular, newly developed, delicate connective tissue. The milder grades of suppurative arthritis, without deep destruction of the synovial membrane, we shall designate as catarrhal suppuration of a joint. In the cases of longer duration, or in the more severe forms of suppuration, all portions of the joint are attacked by the suppuration, the cartilage undergoes fibrillation and here and there becomes necrotic. The suppuration may extend to the bones and the medulla, and, after breaking through the capsule of the joint, give rise to periarticular abscesses, etc. In the worst forms of acute suppurative arthritis putrefactive changes take place, sometimes accompanied by a marked evolution of gas. Suppurative inflammation of a joint may terminate in a *restitutio ad integrum*, in recovery with partial or total stiffness of the joint (anchylosis), or in death.

The *clinical course* of an acute suppurative inflammation of a joint like the knee is characterised by severe pain, by high fever, which often begins suddenly with a chill, by great swelling, and by pronounced disturbance of function. The knee is usually slightly flexed,

and the least attempt at passive motion causes the most intense pain. The skin generally feels very hot, and is reddened. At the outset fluctuation is ordinarily not present, but becomes capable of detection as the amount of pus increases. A characteristic feature of suppuration of a joint is the œdematous swelling of the parts surrounding it or of the entire extremity. The subsequent course of the disease depends upon the nature of the infection, and especially upon whether the suppurative arthritis receives early antiseptic treatment. If the joint is opened and drained antiseptically at an early stage, recovery with a movable joint may still be obtained; and even in neglected cases a *restitutio ad integrum* is possible with the help of antiseptics. In other instances the acute suppuration becomes chronic. Very often recovery takes place with more or less stiffness, or with partial or complete obliteration of the joint. When the joint is obliterated the granulation tissue which is present changes into cicatricial tissue—i. e., a cicatricial connective-tissue anchylosis develops, though sometimes the stiffness is due to bony union of the articular ends of the bones (bony anchylosis; see § 118, Anchylosis). The worst cases terminate in death from pyæmia or septicæmia, the latter coming on with great rapidity in the case of putrefaction of a joint, unless operative measures are very speedily and energetically adopted.

Suppuration of joints in arthropathies is described in § 117, and the spontaneous dislocations which occur in acute inflammations of joints in § 122 (Luxations).

The contractures which take place in the course of acute joint diseases are mainly reflex in their nature (see pages 569 and 575).

The Primary Acute Suppurative Synovitis of Small Children.—Krause has recently described a primary acute suppurative synovitis of small children on the basis of observations made in Volkmann's clinic. The affection occurs not infrequently in the form of catarrhal suppurative arthritis in children from one to four years of age, is always monarticular, and attacks most commonly the shoulder, ankle, elbow, and hip joints. The course is very acute, and is accompanied by the symptoms of a phlegmon; but after freely opening the joint recovery usually takes place rapidly without disturbance of function. Satisfactory results are often obtained even in the cases where the pus has spontaneously ruptured externally, and in neglected cases. Not infrequently spontaneous luxations occur. Krause found the *Streptococcus pyogenes* in the pus. Sometimes suppurative inflammations of joints are observed during early childhood in conjunction with injuries or the acute exanthemata; they are generally caused by the *Staphylococcus pyogenes aureus* or *albus*, and have a pronounced pyæmic character.

Croupous Synovitis.—Many authorities, including Bonnet, have recognised, in addition to the serous and suppurative synovitis, a croupous syn-

ovitis which is analogous to the croupous inflammation of mucous membranes. In the croupous synovitis there are found in the cavity of the joint large amounts of coagulated fibrin; the affected joints are very painful, but only slightly swollen, and fluctuation is absent. The course of this more or less dry arthritis is unfavourable, inasmuch as the joint becomes obliterated in the majority of instances, and firm anchylosis results. As a matter of fact, there are inflammations of joints which run a very dry course; but it seems to me questionable whether in these cases there is really a croupous inflammation of the joint.

Etiology of Acute Inflammations of Joints.—The causes of acute primary inflammations of joints are in the main traumatic, and are chiefly to be ascribed to infection of some injury by micro-organisms. Every suppurative arthritis is due to the presence of bacteria. In the case of a serous synovitis, however, taking cold cannot be left out of account as a primary or exciting cause. Primary acute inflammations of joints very often originate secondarily—i. e., they are either the result of disease of the adjoining tissues, such as the medulla, periosteum, etc., or they are the local expression of a general systemic infection—in other words, they are metastatic inflammations which generally develop simultaneously in several joints. In the latter category belong, for example, the inflammations of joints occurring in the course of pyæmia, typhoid fever, the acute exanthemata, and of pneumonia in consequence of infection by Fränkel's pneumococcus, also polyarticular rheumatism, arthritis urica (gout), gonorrhœal rheumatism, the inflammations of joints arising in the course of syphilis, chronic lead poisoning, etc. We must refer the reader to the text-books on internal medicine for the description of acute polyarticular rheumatism. It will suffice to say here that the entire course of this disease suggests an infection by micro-organisms with localisation in the joints and other serous cavities (the endocardium, for example). The inflammation of the joints is generally serous, but it may occasionally be suppurative in its nature. The *Diplococcus pneumoniæ* of Fränkel and Weichselbaum has been found in the pus in acute articular rheumatism. At all events, there are many different kinds of micro-organisms concerned in the so-called acute polyarticular rheumatism. The acute rheumatism that occurs during pregnancy very frequently runs a severe and protracted course, usually lasting much longer than the pregnancy, and terminating in anchylosis, particularly of the knee and wrist (Noorden).

The Secondary Inflammations of Joints which Occur in the Course of Acute Infectious Diseases (Pyæmia, Acute Exanthemata, etc.).—The inflammations of joints which occur in the course of acute infectious diseases (pyæmia, erysipelas, puerperal fever, measles, scarlet fever, smallpox, typhoid fever, diphtheria, pneumonia, mumps, glanders, dysentery,

etc.) are mostly of the suppurative variety, and the bacterial forms which are characteristic of the primary disease are usually found in the exudate contained in the joint. In the case of pneumonia the suppurative arthritis following infection by Fränkel's pneumococcus may develop before or after the pneumonia itself. The pyæmic inflammations of joints run the course of an acute suppurative catarrh or of an acute pyæmic gangrenous arthritis, and the disease is almost always multiple. If the patient recovers from the pyæmia the inflammation of the joints will ordinarily subside with great rapidity, and not infrequently the joints will regain perfect motion where one would expect stiffness. Other cases run a very chronic course, like cold abscesses.

The inflammations of joints which occur in the course of the acute exanthemata (scarlet fever, measles, small-pox, typhoid fever, diphtheria, dysentery, etc.) present the picture either of acute polyarticular rheumatism or of suppurative pyæmic arthritis. During convalescence from the acute infectious diseases, however, we meet with pronounced, serous, monarticular exudations into the joints which only cause a slight amount of pain; this is particularly apt to happen in typhoid fever. O. Witzel has recently called attention to the frequent occurrence of inflammations of bones and joints during acute infectious diseases.*

Suppuration in Neuropathic Bone and Joint Disease.—Suppuration in neuropathic bone and joint disease is discussed in § 117. The analgesia which is the result of disease of the spinal cord (tabes, syringomyelia, etc.) and peripheral nerves is an important etiological factor in the production of this kind of suppurative arthritis, for the reason that the patients, in consequence of the absence of their sense of pain, neglect injuries which they receive, and this allows suppurative infection to take place.

Gonorrhœal Arthritis.—Gonorrhœal inflammations of joints occur most commonly during the first month of the gonorrhœa. Nolan found that gonorrhœal arthritis developed sixty-four times in the first month, eleven times in the second month, and twelve times later on—in some cases even years afterward (Bennecke). Generally speaking, the joints become the seat of metastatic inflammation only when the gonorrhœa has involved the deeper portions of the urethra, thus allowing the micro-organisms to get into the circulation more easily. Aman has found gonococci in the blood. The tendons and tendon sheaths, bursæ, nerves, eye, endocardium, and pericardium are also sometimes attacked by metastatic inflammation in gonorrhœa. Gonorrhœal inflammations of joints are only rarely caused by the gonococcus; in the majority of

* Bonn, Max Cohen & Son, 1890, p. 146.

ases staphylococci, streptococci, pneumococci, etc., have been found. The pus cocci occur in the exudate either alone or with gonococci. Generally speaking, it is not often possible to detect gonococci in the exudate. Bennecke found gonococci only once in fifty-eight gonorrhœal joints in thirty-eight patients. They are found most frequently in the tissues—e. g., the superficial layers of the synovial membrane, and this explains, perhaps, why they are so rarely present in the exudate. This gonorrhœal inflammation attacks by preference the knee joint, though the affection often occurs in a multiple form involving several joints, and as a rule is serous or sero-fibrinous, very rarely suppurative, in its nature. Quite often there is a very considerable exudation into the joint. In three hundred and eight cases Nolan states that the knee was affected eighty-six times, the ankle fifty-two, the shoulder twenty-nine, the wrist twenty-six, the hip fifteen, the fingers and toes seventeen, etc. Out of one hundred and eighteen cases, only twenty-three were monarticular, and in fifteen cases many joints were involved. The course of gonorrhœal rheumatism in the majority of instances is favourable, and after the joint has been punctured once or twice the effusion disappears entirely, but recurrences of the affection are rather common. There are also cases which run a very chronic course, like tumor albus, arthritis deformans, or chronic articular rheumatism, terminating in partial or complete anchylosis; the severe forms of the disease have a marked tendency to permanent disturbances of the mobility of the joints. There are also markedly malignant cases, and such go on quickly to suppuration of the joint and soft parts. For the treatment, see page 693.

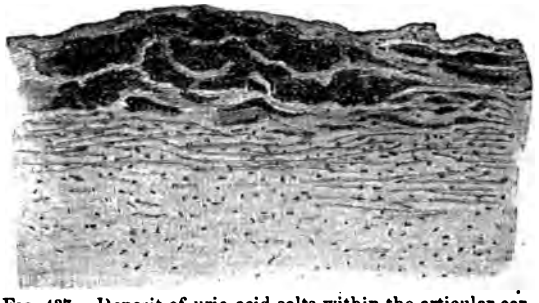

Fig. 437.—Deposit of uric-acid salts within the articular cartilage of the knee in gout.

The Acute Inflammations of Joints which occur in the Course of Syphilis.—In the course of syphilis there are likewise observed monarticular and polyarticular inflammations of joints which are like a monarticular hydarthros of the knee, or, when polyarticular, like acute rheumatism. The chronic syphilitic inflammations of joints are discussed in § 114.

Gout (*Arthritis Urica*).—Gout is an expression of the uric-acid dyscrasia. The blood contains an excess of the salts of uric acid, which are deposited especially in the articular cartilage (Figs. 437 and 438), the

capsule, the ligaments, and in the parts surrounding the joints. Ebstein, to whose painstaking study of gout we are greatly indebted, has produced the disease experimentally in cocks by tying off the ureters and destroying the secreting parenchymatous portion of the kidneys. This very painful inflammation occurs in the form of paroxysms, and most commonly attacks the joints of the toes (*podagra*), less often those of the fingers or wrists (*chiragra*), for the reason that disturbances of circulation more readily take place in the terminal parts of the body. Arthritis urica is mainly a disease of the higher classes, and is more common in England than on the Continent, making its appearance at the earliest about the thirtieth to the thirty-fifth year of life. Gout begins with a serous effusion into the affected joint, which is very apt to be the one between the metatarsus and first phalanx of the great toe. Then follows the deposition in and around the joint of crystals consisting of urate of sodium and compounds of uric acid with calcium, magnesium, ammonia, and hippuric acid. The skin is very much reddened, and is exceedingly tender upon the slightest pressure. Usually a complete *restitutio ad integrum* ensues, but inasmuch as the attacks are frequently repeated, deforming inflammations of the joints may eventually develop, which consist in a fibrillation and abrasion of the cartilage, thickening of the synovial membrane, periarticular tissues, etc. There is also a formation of circumscribed nodules, gout nodes (tophi) as they are called, containing chalky deposits. Furthermore, patients with gout suffer from progressive degenerative changes in the internal organs, especially in the kidneys and walls of the vessels (atheroma of the vessels). The post-mortem examination of individuals who have had this disease reveals with remarkable frequency pulmonary emphysema and chronic interstitial nephritis; also calcification and degeneration of the valves of the heart, particularly those of the aorta, apoplexies of the brain in consequence of atheroma of the walls of the vessels, etc.

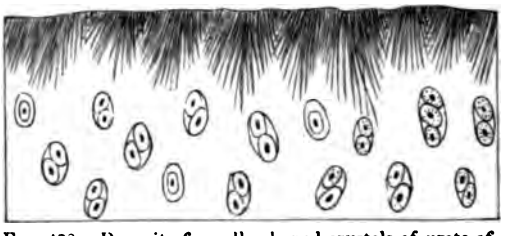

FIG. 438.—Deposit of needle-shaped crystals of urate of sodium in the articular cartilage in a case of gout. × 250.

Acute inflammations of joints occurring in attacks and presenting a clinical picture which is like arthritis urica, are also sometimes observed in the course of chronic lead poisoning.

The Diagnosis of Acute Inflammation of a Joint.—The diagnosis of acute arthritis can in the majority of instances be made with ease from the descrip-

tion given above. In making the examination the diseased side should always be compared with the healthy one. Any exudate which may be contained in the joint adapts itself to the form of the latter. A test puncture with a hypodermic needle—which, of course, must be carried out with every antiseptic precaution—will give accurate information as to the nature of the exudate in the joint, whether it is serous or purulent. For the rest, I must refer the reader to what we have said as regards diagnosis in the chapter on Inflammation (see pages 252, 253).

The Treatment of Acute Inflammation of a Joint.—The treatment of acute serous synovitis, acute hydarthros, consists, at the outset, in maintaining the part in a quiet (elevated) position, possibly with the aid of splints, and in the application of ice. As soon as the inflammatory manifestations, especially the pain, have subsided, the serous exudate which may be present should be caused to disappear by compression with elastic bandages—the ordinary rubber bandage, for example—and by massage practised once or twice daily, and the patient then permitted to walk about. The treatment by rest should not be continued too long a time in acute hydarthros, for the reason that the affection may then easily take on a chronic character.

If the effusion is under great tension, if absorption is delayed, or if the hydrops has become chronic, the joint should be punctured *aseptically*. The area of skin over the joint is carefully scrubbed with soap, shaved, and washed with a five-per-cent. solution of carbolic acid or a one-tenth-per-cent. solution of bichloride of mercury. The effusion in the joint is then compressed with the left hand, and the joint opened with a trocar which has been sterilised by boiling it for five to ten minutes in a one-per-cent. solution of soda (see page 75, Fig. 65), or by heating it red-hot, or with a large hollow needle of an aspirator similarly sterilised, or simply by puncture or incision with the knife. After the exudate has been evacuated the joint can be washed out with a three-per-cent. solution of carbolic or a one-tenth-per-cent. solution of bichloride. In pure serous effusions I usually avoid this washing out, but do it if the effusion is sero-fibrinous and contains flocculi of pus. After puncturing it the joint is immobilised by splints and an antiseptic dressing which exerts pressure. The aseptic puncture of a joint with the trocar, aspirator, or knife is entirely devoid of danger if the rules of asepsis are carefully observed and if pains are taken to prevent the entrance of air into the joint—in short, if the operation is performed with the utmost possible caution.

Treatment of Acute Suppurative Arthritis.—If there is pronounced suppuration in a joint, aseptic puncture followed by irrigation of the joint with a three-per-cent. carbolic or one-tenth-per-cent. bichloride solution may be practised in those cases in which the suppuration is

still in its inception; but if the suppuration is well marked and there is high fever, the joint must be immediately opened by a free incision and drained (§ 31), and, if necessary, resection of the joint (§ 40) must be performed. If the test puncture (with the hypodermic needle) reveals acute suppuration, the expectant treatment by elevation, ice, and immobilising dressings, which used to be employed, should be discarded, and operative treatment by incision and drainage or resection should be straightway adopted in its place. *Ubi pus ibi evacua!* After the operation the joint is placed in a suitable position and carefully immobilised by splints and antiseptic dressings. When the arthritis is suppurative a careful examination should always be made to determine whether periarticular collections of pus are present. In cases where the suppuration is severe, permanent antiseptic irrigation should be used (page 181). In the worst forms of suppurative arthritis with putrefactive changes it is often necessary to perform an amputation in order to save the patient's life. If after suppuration of a joint recovery takes place, with motion in the latter, we improve the motility as much as possible, after the inflammation has completely subsided, by passive motion, massage, and electricity. If recovery takes place with anchylosis, the joint must be made to assume a position which will be as useful as possible for the patient. The ankle and the elbow, for example, should be kept in a right-angled position, but the other joints must be extended.

The treatment of the secondary, metastatic inflammations of joints is precisely the same as for those which are primary. If many joints are attacked by suppuration, and there is a severe or hopeless constitutional disease, one would probably relinquish all idea of adopting energetic operative measures, and simply provide an escape for the pus by incision and drainage, and alleviate any pain which the patient may suffer.

Treatment of Acute Polyarticular Rheumatism.—Acute polyarticular rheumatism is treated by immobilisation of the joints with splints of wood, pasteboard (see page 224), plaster of Paris, or water-glass; by placing the limb in an elevated position, and by administering internally diaphoretics and diuretics, particularly salicylic acid or salicylate of sodium (3.0 to 6.0 grammes *pro die*). I ordinarily give to adults four to six grammes of salicylate of sodium in wafers or a mucilaginous mixture (with aq. dest. and mucilag. gummi. mimos., āā 50.0 grammes) about every two to three hours. If 0.50 to 1.0 gramme of salicylic acid are given in wafers, or the above-described mixture, one should not neglect to make the patient drink a glass of water after each dose, as otherwise the stomach may easily become disordered. I must refer

the reader to the text-books on internal medicine for the rest of the treatment of acute polyarticular rheumatism, including any cardiac complications which may arise.

Treatment of Gout.—The *local treatment of gout* consists in alleviating the pain by placing the part in a proper (elevated) position and in enclosing the inflamed joint in cotton with slight pressure. The joint in question is painted over with fat or vaseline and enveloped with dry cotton, or a hydropathic dressing is applied around it. Lithium, salicylate of sodium, etc., are given internally. Diaphoretic remedies are supposed to shorten the attacks. The patient is put upon a light diet, and Moselle wine with seltzer, or some such beverage, is given him to drink. The morbid diathesis is treated by a moderation in the patient's mode of living, especially as regards alcohol, by a meat diet, which must not be too excessive, and by the use of Carlsbad, Kissingen, Marienbad, Wiesbaden, Levico, Vichy, and other saline-spring waters; the hot baths of Gastein, Teplitz, Wiesbaden, etc., are also worthy of recommendation.

Treatment of Gonorrhœal Rheumatism.—The milder cases of gonorrhœal inflammations of joints are treated by rest in bed, by ice, by immobilising dressings, and by a simple diet. Ice is sometimes not well borne, and local heat (see page 698) may have to be substituted particularly for the pain. Balzer recommends warm turpentine baths from 40°–42° C. (104°–107.6° F.) for 10–20 minutes. From 150–800 grammes of a mixture of equal parts of soap and spirits of turpentine are added to each bath. Internally as much as 4–6 grammes of salicylate of sodium may be given *pro die*, or 3 grammes of potassium iodide, which usually cause a rapid improvement in the pain and inflammatory symptoms. In the case of large effusions puncture and antiseptic irrigation of the joint, as described above, should not be too long delayed. In the rare instances of suppuration of the joint the rules given on page 691 should be followed. For gonorrhœal rheumatism Vogt recommends the injection of a bichloride-of-mercury solution into the joint (0.1 gramme bichloride, 1.0 gramme sod. chlor., and aq. destil. 50.0 cubic centimetres; three to five hypodermic syringes to be injected into the joint each time at intervals of three days). König praises injections of a five-per-cent. carbolic-acid solution. During the acute inflammatory stage of the arthritis the treatment of the gonorrhœa which is present should be deferred, but later, under all circumstances, it must be cured as soon as possible (see Regional Surgery). After the inflammation of the joint has subsided it will often be advantageous to wear an elastic bandage, and a splint apparatus may possibly be necessary, particularly in the case of the

knee, if the latter has been inflamed for some time. I do not think that massage should be used after the subsidence of a gonorrhœal arthritis, for the reason that recurrences of the affection may thus be lighted up, the micro-organisms being again introduced into the circulation and carried off to other portions of the body. I have seen very satisfactory and permanent cures brought about in protracted and malignant cases from Turkish baths, from the local use of heat (104°–122° F.) and from life in southern climates (Riviera, Sicily, Egypt, Tunis). Bier recommends the use of passive hyperæmia (combined sometimes with the local use of heat), which is said to be successful in fresh cases as well.

The symptomatology and treatment of the acute inflammations of individual joints is described in the Text-Book on Regional Surgery.

§ 114. **The Chronic Inflammations of Joints.**—The chronic inflammations of joints are divided, according to differences in pathology, into two main groups, namely, the *dry* (arthritis sicca) and the *exudative* inflammations of joints (arthritis exudativa, with or without a formation of new tissue or of granulations). The subject of chronic arthritis is of very great practical importance, and, among others, Billroth, Bonnet, Volkmann, Ollier, C. Hueter, and König have done much to advance our knowledge of it.

I. **Chronic Serous Synovitis or Arthritis** (*Hydarthros, Chronic Hydrops of a Joint, Chronic Dropsy of a Joint*).—Hydarthros, or chronic articular hydrops, either begins very gradually as such, or it follows an acute serous synovitis.

The pathological changes are essentially as follows: The fluid which collects in the joint is either thin and watery, or it is thick, gelatinous, or colloid. The exudate is sometimes remarkably rich in endothelium (Volkmann's endothelial catarrh). The secondary changes in the cartilage and capsule of the joint are usually slight; but after the process has lasted a long time the synovial membrane becomes thickened, the villi are increased in size and numbers, the joint cartilage becomes thickened and fibrillated, and the synovial membrane grows over the free surfaces of the cartilage (Hueter's synovitis hyperplastica lævis or pannosa). The synovial membrane occasionally projects through the stretched external fibres of the capsule in the form of a synovial hernia. After the hydarthros has existed a long time the ligaments and capsules of the joint become stretched, sometimes to such a degree that the joint loses its normal firmness and becomes flail-like, and displacements, subluxations, or complete luxations of the articular ends of the bones follow. If a rupture of the capsule of the joint takes place spontaneously, or as a result of a traumatism, a periarticular effusion will make its appearance. The neighbouring mucous bursæ which communicate with the joint are often similarly diseased.

The *causes* of hydarthros are traumatisms (contusions and sprains), infection, such as syphilis or gonorrhœa, taking cold, and the presence of loose bodies in the joint.

The *symptoms* are in the main the same as those of an acute serous arthritis, with the single difference that inflammatory manifestations are usually absent. Hydarthros, or chronic serous synovitis, most commonly occurs in the knee, and in this situation the effusion into the joint can best be demonstrated by placing the leg in the extended position. Very often, if the affected joint is moved, a creaking and rubbing can be felt and heard, and is mainly caused by a thickening of the synovial membrane, by hypertrophy of the villi, together with an increase in their number, and by fibrillation of the cartilage, or by the formation of loose joint bodies. The tendency to the formation of free joint bodies (see § 115) in hydarthros occasionally exists in a marked degree. The course of chronic serous synovitis or hydarthros is generally favourable if the disease receives proper treatment, and only in rare instances do we meet with the above-mentioned deforming changes in the synovial membrane, the articular cartilages, or in the entire articular apparatus.

The best treatment for chronic serous synovitis consists in the use of massage (see page 520) and of compression of the effusion by means of rubber or elastic bandages. It is of the utmost importance that the patient should not protect his joint—should not keep it quiet—but rather should use it industriously. If this does not bring about a cure and cause the effusion to disappear, the latter should be removed in the manner described above, by aseptic puncture, with or without a subsequent washing out of the joint with a three-per-cent. solution of carbolic acid or with a one-tenth-per-cent. solution of bichloride of mercury. After the puncture the joint must of course be immobilised in a suitable (elevated) position during the next few days by an antiseptic dressing applied so as to exert pressure. If the reaction following the irrigation is too severe, it should be combated with ice. As a general thing, simple evacuation of the effusion by puncture, without antiseptic irrigation, will suffice in the majority of cases of hydarthros. A few days after removing the effusion the joint should be massaged and vigorously moved, and from time to time enveloped in an elastic bandage. Any recurrences which may take place can be speedily cured by massage, elastic compression, and movement of the joint. The treatment at one time much in vogue, by irritation of the skin (tinct. of iodine) and by the administration of internal remedies (tartar. stibiat.), has very properly been abandoned, and keeping the joint quiet is actually injurious. I never make use of the injection of tinc-

ture of iodine into the joint—a procedure by no means devoid of danger. Loose joints caused by a stretching of the joint apparatus from chronic effusions are treated according to general rules. In two cases I excised a portion of the stretched capsule of the knee-joint, and made the rest of the capsule smaller by taking a fold in it. The result was excellent; in both cases the joint became normally movable.

II. **Chronic Articular Rheumatism** (*Rheumatismus Chronicus Articulorum, Polyarthritis Rheumatica Chronica*).—By chronic articular rheumatism we understand an inflammation of the synovial membrane running an exceedingly slow course, which occurs almost exclusively in adults, generally after the thirtieth to the fortieth year, and always attacks several joints. There is generally a gradually increasing disturbance in the function of the joints, which ordinarily in the end leads to complete stiffness or anchylosis of the joint. In exceptional cases chronic polyarticular rheumatism has been observed in children and young adults.

Etiology of Chronic Articular Rheumatism.—The etiology of chronic articular rheumatism is varied. Joint inflammations with very different causes can run a course like chronic rheumatism. The real cause of chronic rheumatism is unknown; it has nothing to do with acute articular rheumatism, does not become complicated by cardiac affections, and is not influenced by the salicylic preparations. Among predisposing factors may be mentioned catching cold, being wet through, damp dwellings, poverty, nervous exhaustion, and previous joint affections. The disease almost always attacks adults, and only exceptionally are severe cases observed in children with deformities of the joints, as in arthritis deformans. It has not yet been proved that the disease has a genetic connection with organic or functional diseases of the nervous system, so that it could be regarded as a central or reflex tropho-neurosis. As in the case of acute articular rheumatism, the part played by micro-organisms in the etiology of the disease has not yet been made sufficiently clear. Schüller found in chronic rheumatic joint inflammations with the development of villi, but without suppuration, short thick bacilli, which could be cultivated best at 25° C., and in the dark; by inoculating rabbits a characteristic clinical picture of the disease is said to have been produced. In my opinion, the majority of cases of chronic articular rheumatism are due to bacterial infection. Gonorrhœa is sometimes a cause (see page 688, Gonorrhœal Arthritis). Chronic articular rheumatism occurring later in life seems to be related to arterio-sclerosis, and in such case might be regarded as a disturbance of nutrition in the joint. Judging from the very chronic course of the disease, it seems possible that there may be several causes or different kinds of infection which act at one time or successively.

The *anatomical changes* which occur in chronic articular rheumatism consist essentially in a chronic inflammatory formation of new connective tissue in the synovial membrane and surrounding parts

which have a tendency to shrink and become hard and dense, in a fibrillation of the cartilage, and in a substitution for the latter of vascular connective tissue. The connective-tissue metaplasia of the cartilage is brought about mainly by growth on the part of the synovial membrane, though it is very largely promoted by the increased formation of medullary spaces in the deeper layers of cartilage, and by inflammatory changes with a formation of new vessels in the subchondral medulla. As the new formation of connective tissue increases, the cavity of the joint grows steadily smaller. The stiffness of the joint, the anchylosis, is at the outset due to connective-tissue adhesions which may eventually ossify, the process spreading from the spongiosa until the entire joint may become filled with bone. Chronic articular rheumatism never leads to suppuration, and never to true caries, the pathological changes presenting more of a similarity to arthritis deformans, except that in the latter disease there is more an increased growth of cartilage, while in the former the cartilage is replaced by vascular connective tissue. But deformities of the joints, subluxations, and luxations develop in chronic articular rheumatism as they do in arthritis deformans.

Chronic articular rheumatism either follows an acute rheumatism, or it begins insidiously as a chronic disease which lasts many years, and is very frequently—in fact, as a rule—incurable. Gradually many different joints become affected, and, in rare instances, all the joints of the body.

The subjective symptoms consist in sharp, severe pains felt now in this and now in that joint. The movements of the joints, particularly in the morning, after the night's rest, are limited and cause pain; but during the day, after the patient has used his limbs somewhat, the mobility of the joints improves. In other instances the joints are so painful that no movements at all can be performed. The joints are usually somewhat swollen; and in many cases—i. e., in the so-called fungous form of articular rheumatism—the growth of connective tissue is so considerable that the joints present the appearance of tumor albus. If the joints are moved, a creaking or crackling friction sound, due to the newly formed connective tissue and to the fibrillation of the cartilage, can very frequently be made out. As a rule, subacute exacerbations of the subjective and objective symptoms take place at irregular intervals, the joints become steadily stiffer, and the muscles atrophy more and more, so that these pitiable individuals grow constantly more helpless, and death often occurs from general marasmus or some intercurrent disease. In other cases the process comes to a standstill with partial or total anchylosis of the affected joints. I

saw a divinity student, forty years of age, who had complete anchylosis of both hips, both knees, the right elbow, and the left wrist; and Percy found anchylosis of all the joints of the body in a French officer who died in his fiftieth year. The skeleton of this officer, who had suffered from chronic articular rheumatism contracted in his campaigns, has been preserved in the École de Médecine, and forms, to all appearances, a single piece of bone.

The diagnosis of chronic polyarticular rheumatism can, in all probability, be readily made from what has been said above; but the milder cases are often difficult to differentiate from gout and arthritis deformans. We have also made the prognosis sufficiently clear.

The treatment of chronic polyarticular rheumatism generally demands a great deal of patience, and even then, I am sorry to say, is often entirely unsuccessful. In cases which are not of long standing, massage and methodical exercise of the joints should be tried in combination with hydrotherapy (baths, steaming, douches, etc.). The joint should not be kept quiet in the early stages of a chronic rheumatism. If massage and movement of the joint are too painful, they must be carried out occasionally under chloroform anæsthesia. I have seen very satisfactory and permanent cures obtained by this treatment in cases which had not existed too long a time. Furthermore, hot springs, such as Gastein, Teplitz, Wiesbaden, Wildbad, and Ragatz-Pfäffers, a residence in warm climates, and particularly the use from time to time of local heat, are very valuable. Heat may be employed in the form of hot air, steam, packs, etc. Internally, cod-liver oil and iron, potassium iodide, or vinum colchici seminis have been recommended; the use from time to time of the salicylates is very serviceable. But often, on account of the severe pain, massage cannot be carried out, or the joints may already have undergone too extensive changes. In such cases, which are generally of long standing, we are often compelled to confine ourselves to orthopædic treatment, placing the diseased joints in a good position, under chloroform anæsthesia, and immobilising them by plaster-of-Paris splints. As a result of the rest given the joints by the plaster of Paris, the pain ordinarily becomes less, but at the same time the occurrence of anchylosis is favoured. After having kept the diseased joints quiet by splints for a long time, it has been my experience that all hopes of the possibility of obtaining a cure with a movable joint must generally be given up, and a recovery with anchylosis be striven for. Sonnenburg, Müller, and others have recently obtained good results from operative treatment, consisting either in arthrotomy and antiseptic irrigation, with or without drain-

age, synovectomy, and, in rare cases, in resection. Schüller recommends injections of sterilised iodoform-glycerine-guaiacol (ten to fifteen grammes of a mixture of five grammes of iodoform to sixty to one hundred grammes of glycerine and twenty drops of purified guaiacol). I have not seen any success from intra-articular injections in chronic rheumatism, but I believe, with Sonnenburg and Schüller, that chronic articular rheumatism in its later stages, especially if there is great pain, should receive operative treatment more frequently and earlier than it ordinarily does.

III. **Chronic Suppuration of Joints.**—Every suppuration of a joint is the result of infection by micro-organisms. The infection takes place in conjunction with a traumatism, for example, or by way of the circulation, or in consequence of the extension to the joint of a suppurative inflammation in the surrounding parts (medulla, periosteum, soft parts). In chronic suppuration of a joint the synovial membrane is usually the seat of an inflammatory infiltration and is covered with fibro-purulent masses, the cartilage is cloudy and fibrillated, and losses of substance develop in it (cartilage ulcers); occasionally large portions of the cartilage necrose and separate from the underlying parts, or the cartilage is completely destroyed. The suppuration very often spreads to the medulla, the periosteum, and the periarticular tissues. The joint becomes more or less altered according to the severity and duration of the suppuration, and in pronounced cases which have existed for a long time fibrous or bony anchylosis usually develops when recovery takes place, as we remarked before in discussing the subject of acute suppurative arthritis.

We shall first take up that form of chronic suppuration of joints which is due to tuberculosis.

IV. **The Chronic Fungous and Suppurative (Tubercular) Inflammations of Joints—Tuberculosis of Joints—Tumor Albus—Tubercular Caries of Joints—Fungus of Joints.**—All these terms indicate one and the same disease, viz., tuberculosis of joints or tubercular arthritis.

Tubercular arthritis either begins primarily in the synovial membrane or it is secondary to tubercular foci in the bone. Müller's statistics, obtained from König's clinic, show that in two hundred and thirty-two cases of tubercular arthritis one hundred and fifty-eight started in the bones, forty-six in the synovial membrane, and in twenty-eight cases the point of origin was uncertain. We remarked on page 634 that the anatomical structure of the medulla is especially favourable to a deposition from the blood of the tubercle bacilli, and we likewise emphasised the fact that tubercular arthritis develops very often after the reception of some traumatism. Later investigations

have led König to conclude that the primary form, beginning in the synovial membrane, is more common than the one secondary to disease of the bone. I agree with him fully. The general subject of tuberculosis and of tuberculosis of bone is described in § 83 and § 105, and therefore we shall confine ourselves here to the presentation of the tuberculosis involving joints.

The Pathological Changes which Occur in Tubercular Arthritis.—The pathological changes which occur when a joint is infected by tubercle bacilli, no matter whether the infection is primary in the joint or secondary to similar disease in the medulla, periosteum, or periarticular soft parts, are as follows: The bacilli enter by one or more points of infection, and are, so to speak, planted in different parts of the joint, where they give rise to the

FIG. 439.—Large infarct-shaped subchondral tubercular focus in the head of the femur, which is in an advanced stage of demarcation; the articular cartilage is lifted up like a pustule. Early resection. Five-year-old girl. Cure.

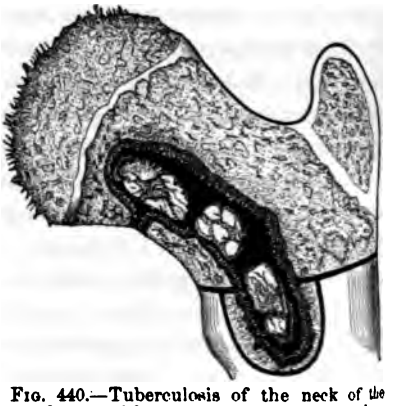

FIG. 440.—Tuberculosis of the neck of the femur with three sequestra. Secondary tuberculosis of the hip-joint; the cartilage of the head of the femur is destroyed. Resection of the hip. Eight-year-old boy (Volkmann).

development of tubercles which have the structure that we described on a previous page (415). The synovial membrane undergoes inflammatory changes and is filled with characteristic greyish-white nodules, and as the tuberculosis advances it is possible to distinguish three different forms of the disease, which, to be sure, merge into one another: (1) the *pure miliary form*, without the formation of a spongy, so-called fungous tissue, (2) the *fungous form*, and (3) the *fibrous*, with the formation of lardaceous thickenings. The fungous form of tubercular arthritis is the most common, and in it the synovial membrane becomes changed into a spongy, red granulation tissue filled with tubercles, while during the early stages the joint contains a serous or sero-fibrinous exudate (hydrops tuberculosus), and later on pus in which there are generally small particles of cheesy matter (cold, tubercular, suppurative arthritis). According to König this sero-fibrinous effusion is the first symptom within the joint, both in the form that starts in the bone and the one that is primary in the synovial membrane. Rice bodies are usually formed in tubercular joints, and are due mainly to a

oid degeneration (coagulation necrosis) of the synovial fluid (see page 579 age 581). The tubercular granulation tissue in course of time grows into rts of the joint, pushes its way over artilage and ligaments, and pene- into the bone and medulla, etc.; in wherever the tubercular granula- issue develops the original tissue is yed. In the case of tuberculosis of the portion of the latter which is ed by the disease either necroses *in* Fig. 439), or several isolated seques- e formed (Fig. 440). In the caput is, for example, very characteristic form sequestra are frequently ob- l (Fig. 439) which are similar to the led infarcts—i. e., the necrosis of tis- sulting from occlusion of the termi- afferent arterial vessel. These in- have the form of a wedge which ponds to the distribution of the terminal branches of the affected ves- sels. The cuneiform sequestra which are met with in tuberculosis of bone are prob- ably due in the same way to the plugging of the terminal artery at the apex of the wedge with tubercle bacilli. If the tuber- culosis begins in the bone the articular cartilage either becomes perforated like a sieve by the tubercular inflammation, or it is raised from the underlying parts more or less *in toto*, as in Fig. 439. In the later stages large portions of articular cartilage may be separated *in toto* from the bone, or the cartilage may be completely de- stroyed, as in Fig. 440. It is very fortu- nate for the patient if the tubercular pro- cess, for example, in the epiphysis of a long, hollow bone does not attack the joint but breaks through externally to it. This extra-articular breaking through of bone tuberculosis in the neighbourhood of a joint is a rather common occurrence. After the tubercular inflammation of the joint has broken through the joint capsule there follows a development of periartic- ular tubercular inflammation and suppura- tion with extensive collections of pus—the so-called congestion, cold, or gravitation ses which we have spoken of in a previous chapter. Not infrequently tra-articular tubercular abscesses originate by infection through the

FIG. 441.—So-called "wandering of the acetabulum" in coxitis ("intra-acetabular dislocation").

2.—Tubercular kyphosis of the spine in a boy of twelve.

lymph channels without a rupture of the capsule having taken place, and without the existence of any visible communication between the intra- and extra-articular suppurative processes. If the lymph glands connected with the joint become infected by tuberculosis, the danger of the tubercle bacilli being carried further—in other words, the danger of a general tuberculosis—becomes more imminent. Very often the tubercular inflammation works its way outwards through the skin spontaneously, and gives rise to fistulæ which frequently pass a long distance through soft parts and bone.

Fig. 443.—Tubercular contracture and anchylosis of the knee in a six-year-old boy. Cuneiform resection followed by healing in the extended position.

The destruction of tissue which takes place in tubercular arthritis, and is the result of the progressive change of bone, cartilage, and soft parts into tubercular granulation tissue, which breaks down and undergoes cheesy degeneration and suppuration, is sometimes very considerable. The entire head and neck of the femur may thus be destroyed by caries and necrosis, and not infrequently extensive ulcerative processes lead to perforation of the acetabulum. Very often the latter becomes enlarged in an upward direction, and the head of the femur, following the change in the shape of the acetabulum, is caused to assume a higher position—a phenomenon which is called "wandering of the acetabulum" (Fig. 441). In the spinal column entire vertebræ may be destroyed, giving rise to corresponding deformities, especially kyphosis or Pott's hump (Fig. 442). Furthermore, in tuberculosis of the vertebræ, the cold, congestion abscesses which gradually burrow downwards may attain a considerable size; they usually follow the course of the ilio-psoas muscle, and may eventually come to the surface in the thigh beneath Poupart's ligament.

If left to itself a tubercular focus may heal up at any stage of its existence. Recovery often takes place only after the joint has become completely obliterated or anchylosed, but not infrequently the cure is only apparent and temporary. If the joint has not been immobilised in a proper position while the tubercular disease was in progress, contractures are very liable to take place; and if these affect the knee or hip, the use of the leg may be seriously interfered with or rendered impossible (see Fig. 443).

The Development of Tubercular Arthritis after the Injection of Tubercle Bacilli into the Joints of Animals.—If pure cultures of tubercle bacilli are injected into the joints of guinea-pigs there will be observed, after the lapse of four to six days, an increasing inflammatory swelling and exudation into the joints under consideration, and towards the end of the third week the

presence of tubercle bacilli can be plainly made out, and pus will be found in the joints. Pawlowsky states that the tubercle bacilli are located mainly in the lymph passages and connective-tissue cells. If intravenous injections of attenuated (weakened) cultures of tubercle bacilli are practised in rabbits, the typical picture of tubercular disease of joints will sometimes be obtained only after four to five to six months, while the other organs will remain healthy (Courmont, L. Dor).

Tubercular arthritis runs an exceedingly chronic course, as a rule, and often lasts many years. The disease most commonly attacks children, though adults of all ages are not exempt from it. The joints most frequently affected are the knee, the hip, the astragalo-tibial joint, and the joints of the tarsus. Tubercular arthritis generally begins very gradually, but in rare instances is more or less acute in its onset. Very acute cases are sometimes observed in young children from one to two years of age, in which considerable pus is formed, with cellulitis of the soft parts and a rise of temperature. The pus contains tubercle bacilli. The prognosis of these cases is usually good if the pus is evacuated promptly, and they are often cured by a simple arthrotomy, just like tubercular peritonitis. If we leave out of consideration this special form, the course of tubercular arthritis is usually as follows: The first symptoms of tuberculosis involving the knee-joint of a child, for example, are a proneness to fatigue and a slight limp or dragging of the leg in walking. After walking for some time, or if pressure is made on the joint, the child complains of pain. The first objective symptom is generally a moderate amount of swelling, which causes the furrows beside the patella to become less plainly marked than upon a healthy knee. The initial symptoms manifested by joints which are more deeply placed are not so apparent as they are in the knee. As the disease progresses the swelling of the knee gradually increases, and the normal contour of the joint disappears to a greater and greater extent. The swelling feels rather hard, or it is more soft and spongy, and is caused either by a thickening of the synovial membrane and periarticular connective tissue, or, as in primary osseous tuberculosis, by enlargement of the articular ends of the bones. The skin is ordinarily more or less tense, and presents a white, waxy appearance, which gave rise to the term tumor albus, formerly used to designate this condition. As the swelling becomes greater the pain in the joint increases, and is made worse by pressure and attempts at motion. The pain, however, is not always felt in the diseased joint, as in tubercular inflammation of the hip (coxitis), for example, the children very often complain of pain in the knee, which might lead an inexperienced person to search for the dis-

ease in the wrong place. This pain in the knee accompanying tubercular coxitis is particularly apt to be present when there is tubercular disease of the medulla, the pain shooting through the latter down to the lower epiphysis; the phenomenon used to be looked upon as a reflex manifestation. Standing and walking eventually become impossible, and the tubercular inflammation causes the joint to grow more and more immovable. The knee and elbow are usually flexed to a greater or less extent, and the hip assumes a position of flexion, abduction, and outward rotation. At the outset the abnormal position of the joints can be corrected under chloroform anæsthesia, but later this cannot be accomplished without operative interference. The distorted positions of the joints—the contractures—may sometimes, as a result of improper treatment, become very excessive, as illustrated in Fig. 443; but contractures like this can always be easily prevented by the use of retentive dressings applied at the right time.

Attempts have been made to explain this abnormal position assumed by inflamed joints by (1) the mechanical theory advanced by Bonnet, and (2) by the reflex theory. Bonnet demonstrated by intra-articular injection of a liquid that the joint thus treated assumes a position in which its capacity is greatest—i. e., increasing its contents forces a joint like the knee to become flexed. According to the second theory, a reflex muscular contracture is produced by the irritation of the synovial membrane. Both theories are right as far as they go, but by themselves are not sufficient to answer the question—a fact which Volkmann has correctly insisted upon. It must be borne in mind that the patient instinctively places his joint in a position which diminishes the pressure on the joint surfaces and causes him the least pain. Moreover, the mechanical conditions connected with the use of the diseased extremity, the longitudinal growth of the bone, and subsequently the changes which take place in the shape of the articular ends of the bones, have an influence upon contractures (see pages 569 and 575).

The further course of tubercular arthritis—sometimes called the *second stage* of the affection—is characterised by an increase of all the pre-existing symptoms, especially the swelling, fixation, and pain, and, in addition, there are very often manifestations of suppuration in the joint; in other words, fever develops, the joint becomes very painful at some particular point, and, finally, fluctuation can be detected. Suppuration in the joint is either accompanied by inflammatory manifestations of variable intensity, or it runs its course as a cold abscess. The amount of pus which is present is by no means constant, being in some instances very considerable, while in others the formation of pus is slight, although the destruction of the articular ends of the bones

may be very marked. Permanent deformities develop in consequence of these changes in the bones, as well as the so-called pathological or spontaneous dislocations. The anatomical changes which follow suppuration in a joint, the development of periarticular abscesses from rupture of the pus in the joint through the capsule or from infection through the lymphatics, the occurrence of extensive gravitation abcesses, etc., have all been described above.

The patients' *general condition* is ordinarily very much altered for the worse; they are emaciated, anæmic, without appetite, and not infrequently have diarrhœa and more or less fever.

Tubercular arthritis terminates either in recovery, or in death from systemic tubercular infection, from tuberculosis of the internal organs, especially the lungs and intestine, from increasing marasmus, from amyloid degeneration, or from some intercurrent disease. Tuberculosis is the most common cause of death. Of one hundred and thirty-five cases of tubercular arthritis which ended fatally, Albrecht states that sixty-four were due to tuberculosis, twenty-three to marasmus, and fourteen to amyloid changes; while in thirty-four the cause of death was unknown. Billroth maintains that the danger of pulmonary tuberculosis is greater after tubercular arthritis occurring in the upper extremity than when the disease affects the lower.

As a general thing it requires a very long time, often years, for recovery to take place spontaneously from tubercular arthritis. In such cases there is a gradual abatement of the local manifestations, the general health improves, and any fistulæ which may be present close up. When spontaneous recovery takes place from a pronounced tubercular arthritis with fistulæ, the joint which has been affected always becomes stiff. If no appreciable suppuration has occurred, recovery not infrequently follows without operative interference and with perfect motion in the joint in question. It is scarcely possible to say with certainty when joints which have been affected by tuberculosis have become entirely well, for relapses have taken place even after anchylosis has existed for years. With the modern methods of performing surgical operations we are able to give a more favourable prognosis, both as regards the preservation of the joint and the life of the patient. Nevertheless, the prognosis of tubercular arthritis, as Billroth has remarked, is in so far unfavourable, as such individuals do not reach an advanced age. There are, for example, only comparatively few people with anchylosis due to tuberculosis who live to be more than forty or fifty years old, and only the minority of children who have been operated upon for tubercular caries of a joint, and cured, attain adolescence.

Treatment of Tubercular Arthritis.—The therapy of tubercular arthritis comprises local treatment of the diseased joint, and measures designed to improve the general health and render the system capable of successfully carrying on the struggle for existence with the tubercle bacilli. This constitutional treatment is described on pages 431 and 434 (Constitutional Treatment of Tuberculosis and Scrofula).

Inasmuch as tubercular arthritis gets well, though very slowly, under proper local and constitutional treatment without operative interference, it would be entirely wrong to immediately subject every case of tuberculosis of joints to operation. Therefore, at the beginning of the tubercular arthritis the local treatment should be directed towards securing absolute rest for the joint by means of hardening dressings (see § 54, plaster of Paris, water-glass), or some of the various kinds of splints (see § 53), or by permanent extension (see § 55), the latter being particularly applicable for the hip. Sayre and Taylor have invented ingenious extension appliances for the lower extremity which enable the patient to walk about. It is also very advantageous in the case of coxitis to place a raised sole under the foot of the sound side, and, by using crutches to walk with, thus keep in suspension the diseased leg, which should be maintained in a fixed position by a Thomas splint (see Regional Surgery, Vol. III, page 715). Hydropathic applications or ice may also be employed for acute or subacute exacerbations which are accompanied by pain. If contractures of the joints are already present when the case comes under observation, they must be gradually overcome by retentive (see page 220) or extension dressings, often with the aid of chloroform anæsthesia. Great care must be taken in correcting the position of a joint which has become distorted; it will often be impossible to remedy matters all at once, and the desired result will have to be accomplished gradually in several sittings. Each time that the contracture is improved the joint should be immediately fixed in its new position by a plaster-of-Paris dressing. Massage should never be practised at the beginning of a tubercular arthritis, as I have repeatedly seen severe constitutional tubercular infection caused by quacks who have prescribed it.

Injections of sterilised ten-per-cent. iodoform oil or ten-per-cent. iodoform glycerine (Bruns) are exceedingly valuable at the commencement of the tubercular inflammation of a joint, and later on when fistulæ have developed. The manner of preparing and sterilising the iodoform-oil emulsion is described on page 650. According to the age of the patient and the size of the affected joint, about every two to four weeks from two to five to ten grammes of the above-mentioned mixture are injected into the joint and scattered through the latter as far

as possible by careful motion and gentle massage. I have seen very remarkable success obtained by these iodoform injections. Injections of three-per-cent. carbolic acid, chloride of zinc (seven to ten drops of a ten-per-cent. solution at intervals of three to seven days at different points in the vicinity of the joint or of the tubercular focus—Lannelongue), arsenic (acid. arsenios. 1 to 1,000, one to two hypodermic syringefuls every day, combined with the internal administration of 0.004 to 0.012 grammes of arsenic *pro die*), iodoform ether, balsam of Peru, cinnamic acid, etc., have also been recommended.

The treatment of tubercular arthritis by Koch's tuberculin has been discussed on page 431. I have not seen any satisfactory results from its use. Bier's treatment by constriction for the purpose of causing passive congestion is described on page 431, and the other methods for treating tuberculosis in § 83.

It is not always an easy matter to decide whether operative measures are necessary, for the simple reason that one cannot always be sure of the exact nature of the pathological changes which are present. In former times, when the antiseptic method of treating wounds was first introduced, surgeons went too far and performed resections of joints too often, particularly in the case of children who suffered from tubercular arthritis. But at present conservative treatment is employed as much as possible, and many joints, which would formerly have been sacrificed by performing total resection, are now saved by iodoform injections, by excision of the synovial membrane, or by scraping away the diseased tissue. Conservatism should, however, not be carried too far, and some surgeons even to-day are in favour of early and radical operative measures in the treatment of tubercular arthritis. The frequency of the occurrence of tubercular sequestra shows that early operative treatment is often indicated.

Richet, Kocher, and Vincent have recommended ignipuncture or punctiform ustion made with the fistula tip of the Paquelin cautery or with the galvano-cautery. I believe that this procedure is suitable for tuberculosis of the synovial membrane which has not become too extensive; but after the fungous granulations have passed into the stage of suppuration energetic operative measures are required. The joint, after being artificially made bloodless, is opened and the diseased parts then removed with great care by means of scissors, forceps, and the sharp spoon; but typical resection of the articular ends of the bones should be performed only in extreme cases (see § 40). If the tuberculosis is purely of the synovial variety, and the bones are healthy, we should, of course, preserve the latter and content ourselves with excision of the diseased membrane (arthrectomy, synovectomy). Early

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as well as late resection of all children's joints, with the exception of the hip, should be confined to as small a number of cases as possible; energetic scraping away of the diseased bone with the sharp spoon, but sparing the epiphysis, or extirpation of the diseased synovial membrane, but leaving the bone untouched or removing some of the cartilage, will almost always be found sufficient. By performing early arthrectomy with preservation of the articular ends of the bones in their entirety, or as much of them as possible, a permanent cure can often be obtained, and that, too, with a movable joint, a fact which is attested by numerous cases. Amputation is only permissible in cases where the saving of life comes into the question, where the destructive processes have become very extensive, or where the patient cannot survive the long period of time required for a resection to heal. Other complications are treated according to the general principles which apply to them. Cold abscesses can with impunity be freely opened, thoroughly scraped out and drained. It is very important to recognise a tubercular focus in the neighbourhood of a joint before it breaks through into the latter, and to remove it with the sharp spoon. After every operation for tubercular arthritis the wound should be disinfected as carefully as possible to prevent infection with bacilli from the wound. Iodoform and iodoform gauze seem to be the most suitable dressing materials, especially for packing the joint. In most cases I do not suture the wound, but pack it with sterile or iodoform gauze. In the case of the knee, I leave the two sides of the wound open, and over the aseptic dressing apply a plaster splint, which is kept on for four to six weeks. When a tubercular inflammation of a joint has got well, some suitable splint apparatus, such as one of those devised by Sayre, Taylor, or Thomas, should be worn, especially on the lower extremity, to support the limb, which will still be weak. If any abnormal conditions, such as contractures, follow a tubercular arthritis, they may have to be treated by tenotomy of the shortened muscles—or, rather, tendons—by resection, arthrotomy, or by a wedge-shaped osteotomy, below the trochanter, for example, when the contracture involves the hip, unless they can be stretched under anæsthesia or gradually overcome by extension or retentive appliances (see page 220).

The treatment of tuberculosis of the individual joints will be described in the Regional Surgery.

V. **The Syphilitic Diseases of Joints** (see also § 84, Syphilis, and page 652, Syphilis of Bone).—The syphilitic diseases of joints have lately been frequently and accurately described by such men as Schüller, Gies, Falkson, etc., and their occurrence can be readily understood if

we bear in mind that syphilis is a specific infectious disease. The joints become affected in the course of syphilis, sometimes primarily and sometimes secondarily, after syphilitic disease in the surrounding parts, particularly the periosteum, medulla, and the epiphyses. The syphilitic inflammations of joints may be met with during the early stages of the disease at the time of the febrile eruption, or during the later periods. Two main classes of syphilitic joint disease may be distinguished: first, simple inflammatory affections without specific new-formations; and, second, those in which there are characteristic syphilitic formations, particularly gummata. The early forms are, in the main, serous synovites, which occasionally make their appearance in a manner analogous to acute polyarticular rheumatism. The inflammations of joints which occur in the later stages of syphilis have, as a rule, a pronounced chronic character, and are generally connected with the formation of gummatous deposits in the periosteum, the medulla, and the synovial membrane. After the gummatous nodules have come to the surface and ruptured externally characteristic ulcerations occasionally develop. In these late syphilitic inflammations of joints there will frequently be found in the joint a gummatous or carious destruction of the bones and sharply defined circumscribed losses of substance, or radiating, glistening white cicatrices in the cartilage, together with fibrillation of the latter, while in other instances a connective-tissue growth in the synovial membrane, taking the form of indurations or of villi, may be more prominent. The pathological changes at the first glance sometimes look like those which occur in arthritis deformans. Many cases run a course with a very gradual increase in the amount of swelling, and resemble clinically tumor albus, but the pathological changes are very different from those of tubercular arthritis. In rare instances the gummatous nodes occur in the synovial membrane in a miliary form and may be macroscopically mistaken for tubercles, and then only a microscopic examination and other manifestations of syphilis which may be present will clear up the diagnosis. The indurated, villous connective-tissue growths, the losses of substance and the cicatrices in the cartilage, and the gummatous, carious destruction of bone are characteristic of syphilitic disease of joints. An acute, subacute, or chronic serous arthritis may also occur in the later stages of syphilis, and primary suppurative inflammation of a joint will be encountered in rare instances—for example, when syphilis is complicated with gonorrhœa, etc. The congenital joint affections occurring in children, which are usually chronic, rarely acute or subacute, originate mainly in primary changes in the epiphyses and epiphyseal cartilage; the bone is enlarged, and joint symptoms

are either absent entirely at the outset or there is a synovitis generally serous in character. In the later stages the above-described joint affections may appear *secondarily*. There are, however, congenital syphilitic inflammations of joints which are suppurative at the start.

The therapy of the syphilitic inflammations of joints consists, in the first place, in a proper local treatment conducted according to the rules which have been given for diseases of joints, and, secondly, in a general antisyphilitic treatment, the best being inunctions, and the next best potassium iodide, etc. (see § 84, Treatment of Syphilis). The antisyphilitic treatment usually has a very noticeable effect, and hence an early diagnosis is of great importance.

VI. **Arthritis Deformans or Malum Senile.**—This affection is in every respect the opposite of tubercular arthritis. Suppuration or caries never occurs. The disease attacks individuals who are old or past the prime of life, and almost always involves several joints. As a rule, it causes deformities in the joints, which very gradually become more marked, while recovery—i. e., a complete *restitutio ad integrum*—never occurs, and arrest of the process only rarely.

The *pathological changes* which take place in arthritis deformans consist (1) in degenerative processes in the cartilage and bones, and (2) in hyperplasia of the bones, cartilage, and soft parts. A fibrillation occurs in the more superficial layers of the ground substance of the hyaline cartilage, while a localised cracking and softening are produced in the deeper layers by the vascular medullary spaces of the underlying bone pushing their way into the cartilage. At the same time, particularly at the free borders, a growth of cartilage occurs taking the form of knob-like tuberosities, which subsequently, for the most part, ossify (Figs. 444, 446). In consequence of the degenerative fibrillation and softening of the cartilage (arthritis chronica ulcerosa sicca) the latter may completely disappear, exposing the uncovered bone, which then, by the friction produced in the movements of the joint, develops a smooth, polished surface (Fig. 446, *a*).

Fig. 444.—Coxitis deformans: head of the femur below the tip of the great trochanter; neck of the femur no longer present (Path. collection in Zürich—Volkmann).

The degenerative changes which take place in the bone consist in a lacunar absorption and inflammatory atrophy of the bone tissue, for the most part subchondral. The atrophy of bone is occasionally very considerable, and may lead to the disappearance of the head or entire neck of the femur (Figs. 444, 445). Just as in the case of cartilage, there will be encountered in addition to the atrophy a new formation of bone which is sometimes very marked (Figs. 445, 446). In some cases the atrophy of the bone predominates (Fig. 444), in others the new for-

of bone (Fig. 446). These degenerative and hyperplastic changes in ilage and bone are very characteristic of arthritis deformans. The and ligaments of the joints also become thickened and afterwards ed, and the synovial villi become the seat of an active process of ıtion. Loose-joint bodies 5) are very frequently found oint, but adhesions between ular surfaces of the bones or ion of the joint by newly- connective tissue almost cur.

joints gradually become so d by these changes in the · ends of the bones and by tening and shrinking of the which is sometimes the seat formation of bone, that mo- omes more or less limited ely lost. If the atrophic in the bones predominate t may become abnormally or even loose and flail-like, tendency towards subluxa- complete dislocation (luxa- deformity, as they are These dislocations cannot, e, be kept permanently re- wing to the deformities of of the bone and the socket, the case of dislocations of the head of the femur a new acetabulum formed on the ilium (Fig. 447).

FIG. 445.—Arthritis deformans of the hip-joint: the greatly enlarged head of the femur lies very near the trochanter owing to the disappearance of the neck (Path. Institute at Leipsic).

ıritis deformans is most commonly observed in the hip, knee, ınd shoulder, and less often in joints of the fingers and verte- n the vertebræ the atrophy of bone may cause the development ıl curvatures, especially kyphosis, while the new formation of ay give rise to osseous union between the different vertebræ. s deformans is either monarticular or polyarticular. If monar- it is usually located in a large joint, while the polyarticular ore commonly occurs in the small joints, such as those of the or toes, etc.

still know little about the etiology of this disease, though its cal peculiarities are so characteristic. It may begin spontane- r follow the reception of some traumatism, such as a fracture ıvolves the joint, or come on after some such infectious inflam- as a gonorrhœal arthritis, or after acute polyarticular rheu- The patient's occupation or position in life plays no part in

the causation of arthritis deformans, but his age probably does. I look upon this affection as essentially a senile disorder which, as a rule, can be traced to some exciting cause, such as a traumatism or an infection —it is rarely spontaneous—and gives rise to characteristic atrophy and to hyperplasia of the cartilage and bone, and to thickening and contraction of the capsule.

The *clinical course* of both the monarticular and polyarticular form of arthritis deformans is exceedingly chronic, and it is not an uncommon thing for the disease to last twenty to thirty years. The initial symptoms are those of a chronic arthritis running a course without fever, and consist in stiffness of the joint, particularly in the morning hours, in slight pains, and in the occurrence of crepitating or creaking sounds. Later on the deformities of the articular ends of the bones or of the entire joint become prominent. The movements of which the joints are capable become more and more restricted, or the opposite condition may exist, the joints becoming loose and flail-like. Occasionally acute inflammatory symptoms make their appearance, consisting of fever, increased tenderness and inflammatory swelling of the joint, and an acute effusion of serum. The pain may be excessive. Recovery is extremely rare, the disease ordinarily growing worse very gradually until it is terminated by death from some intercurrent affection.

FIG. 446.—Arthritis deformans of the right knee-joint: *a*, polished and smooth articular surface; *b*, growth of bone and cartilage; *c*, fibrillation of the cartilage; unequal length of the femoral condyles, giving rise to pronounced genu valgum; the transverse diameter of the internal condyle and the longitudinal diameter of the external condyle are shortened (Path. Institute at Leipsic).

Diagnosis.—The very chronic course of the disease, the absence of suppuration and caries, the characteristic deformity of the joints, the advanced age of the patient, and the history of some predisposing cause, are important factors in the diagnosis of arthritis deformans.

The Treatment of Arthritis Deformans.—The sooner arthritis de-
rmans is subjected to systematic treatment by massage and active
d passive movements of the joint,
e greater is the possibility, particu-
·ly in the case of the monarticular
rm, of arresting the further devel-
ment of the disease. In addition
massage and methodical exercise of
e joint, baths in which the entire
dy is immersed in lukewarm water,
sand baths, mud baths, or steam
ths, combined with cold douches—
short, hydrotherapeutic measures
are especially to be recommended.
ıe use of hot springs, such as Gas-
in, Wildbad, Wiesbaden, Teplitz,
ıgatz, etc., and a residence in south-
n climates, are also exceedingly
rviceable. Marked disturbances of
nction, especially in the upper ex-
ɜmity, can be improved by performing resection. The latter has been
peatedly practised for severe pain, the results in some cases being
cellent and in others entirely negative. The operative treatment of
thritis deformans (synovectomy with or without resection of the
ticular surfaces), should, in my opinion, be tried more often than it
considering the hopelessness of other methods of treatment. In
ɜ very rarest cases amputation is indicated on account of marked
nctional disturbances. The other complications, such as the acute
acerbations, dislocations, or loose joints, which sometimes occur, are
ated according to the general rules which apply to these conditions.
ıe internal administration of drugs, such as iodide of potassium,
ɔnite, quinine, iron, etc., is of little use, but a strengthening mode of
ɜ with nourishing food, fresh air, etc., is very important.

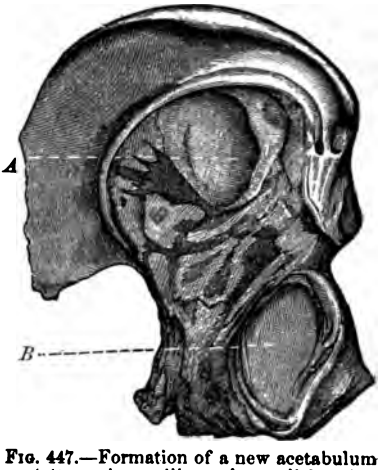

FIG. 447.—Formation of a new acetabulum (*A*) on the os ilium after a dislocation from arthritis deformans in a woman seventy years old; *B*, remains of the original acetabulum (Gutsch).

The Diseases of Joints which occur in Bleeders (*Hæmophilia;* see page
.—Individuals who suffer from hæmophilia are sometimes affected by
·ious kinds of joint diseases, which generally take on a serious character
ing to the presence of the constitutional dyscrasia. Leaving out of con-
eration the different forms of inflammation of joints which occasionally
ɜur in bleeders as well as in other people, there is left a certain definite
ɔup of joint diseases which are clinically and pathologically peculiar to
ɜmophilia, and which are to be regarded, so to speak, as a symptom of this
ease. König has recently described "bleeder joints" very much at length,
d I can fully confirm his statements. These typical joint diseases which are

met with in hæmophilia are characterised by the presence in the joint of an effusion of blood, which may persist in an unaltered state for weeks and then gradually grow smaller, and, if the conditions are favourable and compression is employed, may eventually entirely disappear. But in other instances, particularly if the disease is not properly treated, the effusion of blood is added to by fresh hæmorrhages, the joint becomes gradually more and more damaged, the articular cartilages undergo erosion and fibrillation, and the joint grows constantly stiffer, finally becoming obliterated. If the unfavourable conditions continue, contractures and deformities of the joints develop. It is a very easy matter to mistake a bleeder joint, particularly during the early stages, for hydrops tuberculosus, and later for fully developed tuberculosis (tumor albus). König lost two patients from hæmorrhage because he had thought the articular disease was tubercular and consequently undertook extensive operations. In making the diagnosis of a bleeder joint the personal history of the patient is of the utmost importance, for the reason that the patients or their parents are generally aware of their bleeder disease. It should be noted that it almost always occurs in young subjects, the large effusion of blood usually develops suddenly from some slight traumatism, pain is generally absent, and several joints are commonly affected, some being in the early and others in the advanced stages.

The *treatment* of recent cases consists in placing the limb in an elevated position, in immobilisation and compression of the joint, and subsequently in gentle massage and passive motion. In some instances the joint should be punctured for the purpose of removing the effused blood. Massage should be used cautiously. Cerebral hæmorrhage due to traumatism or pathological processes are sometimes accompanied by effusions of blood in the large joints, which are probably caused by trophic changes in the walls of the vessels, and appear after an injury, for example.

§ 115. **Joint Bodies or Joint Mice** (*Mures Articulares*).—By joint bodies or the so-called joint mice (mures articulares) we mean bodies varying in structure which are formed within joints and are either free or attached by pedicles. Joint bodies anatomically consist of cartilage or of bone, or of bone with a cartilaginous covering, of fibrous connective tissue, of fatty tissue, or of masses of fibrin.

We are able to distinguish etiologically three principal kinds of joint bodies: (1) Concretions made up of fibrin, (2) joint bodies resulting from the breaking off of cartilaginous or bony portions of the articular ends of the bones or intra-articular ligaments by some traumatism, and (3) growths of connective tissue, cartilage, or bone which originally are pedunculated, but later, as a result of atrophy or sudden rupture of the pedicle, become free joint bodies. Out of one hundred and forty-three cases collected by Schüller, eighty-three were caused by traumatism (seventy-eight of the knee-joint), thirty-nine by pathological processes, and in nineteen the mode of production was unknown.

The fibrin concretions—i. e., the fibrin precipitated from the synovia in cases of chronic hydarthros, for example, with or without tuber-

culosis—take the form of round, smooth, or irregularly shaped concrements, usually about the size of a melon seed or grain of rice, which often occur in great numbers. These concrements, from their similarity to grains of rice, are also called rice bodies (corpora oryzoidea). According to König, Landon, and others, all rice bodies that are found in tubercular joints, tendon sheaths, and bursæ are derivatives of the fibrin formed in the synovial fluid and on the surface of the synovial membrane. Schuchardt and Goldmann maintain that the rice bodies are not "fibrinous" products of coagulation formed from the thickened contents of a joint or tendon sheath, but are portions of the synovial membrane or tendon sheath which have undergone coagulation necrosis (Weigert) or fibrinoid degeneration (Neumann). In my opinion, both methods of development of rice bodies occur, but the primary degeneration of the synovial membrane is much the more common, particularly in tuberculosis of the joint. Rice bodies are especially common in tubercular arthritis, and, in fact, the occurrence of these bodies in a joint makes the existence of tubercular disease probable. Such cases sometimes run a very favourable course. (See also pages 579 and 581, Formation of Rice Bodies in the Tendon Sheaths and Bursæ). Occasionally the concrements attain a considerable size—that of a hen's egg, for example, or larger. Small foreign bodies, such as needle points, broken-off synovial villi, a blood-clot, etc., have been found in the interior of the concretions, just as in vesical calculi.

In the second category of cases the free joint bodies are formed from bony or cartilaginous portions of the articular ends of the bones or intra-articular ligaments which are torn from their attachments by some traumatism, such as a blow, a fall, or some other violence. Occasionally the detachment is not complete, and then at some later period there takes place a gradual or sudden separation of the partially detached piece of bone or cartilage. Kragelund was able only by using a great amount of force to partially or completely break off from the femur—generally the internal condyle—but not from the tibia, portions of bone which presented a close similarity to mures articulares, and Poncet saw small fragments of bone torn from the points where the ligaments were attached. Gies, Poncet, Barth, and others have opened the joints of animals, chiseled off portions of the articular surface, and then closed the wound in the joint, which healed by primary union. The behaviour of these free portions of cartilage is as follows (Barth): "Free pieces consisting of bone and cartilage usually become adherent to the capsule and articular surfaces, and are inclosed by vascular connective tissue; the bony portion dies, while the cartilage retains its vitality, grows, and gives rise to a new formation of bone, using the

lime salts of the dead bone. In consequence of vigorous growth of the cartilage, free bodies with an external layer of cartilage and a central bone nucleus may result, and their union with the capsule of the joint becomes severed. Joint bodies that are not united to the capsule are sometimes absorbed, but this is a rare occurrence in man, because the bodies of traumatic origin tend to calcification.

Furthermore, without the reception of any traumatism, larger or small pieces may become separated from the articular ends of the bones as a result of some process which is not as yet understood; these pieces are then covered on their bony surfaces with dense connective tissue which contains cartilage cells, and the loss of substance in the bone from which they came is repaired in a similar manner. König has given the name of *osteochondritis dissecans* to this genetically obscure and circumscribed disease of the articular ends of the bones.

The third way in which joint bodies may originate—i. e., in the form of steadily enlarging growths of tissue attached by a pedicle to some part of the articulation, such as the villi, the synovial membrane, or the articular cartilages—is met with especially in chronic joint diseases, such as arthritis deformans or chronic hydarthros, or after fractures which involve the joint. The growths are made up, according to the point from which they spring, of connective tissue, cartilage, or bone, or bone with a cartilaginous covering, and then by gradual atrophy or by sudden rupture of the pedicle these growths become free joint bodies. In this category belong the free joint bodies formed by growth of the synovial villi or by fibrillation of the cartilage, as well as those which result from the detachment of tumours of cartilage or bone (enchondroma, osteoma), or of the cartilaginous or bony plates in the synovial membrane which may develop in the course of hydarthros and arthritis deformans. As a result of the fibrillation of the articular cartilage occurring in a chronic arthritis, there is often a very excessive formation of cartilaginous villi in which a vigorous circumscribed growth of cartilage cells sometimes takes place. If these formations become loose, hyaline rice bodies analogous to the above-mentioned fibrinous rice bodies develop, having exactly the same form as the latter, and likewise existing in very great numbers. The condition in which there is an excessive growth of fat in the villi is called *lipoma arborescens*, and may give rise to the formation of free joint bodies which are soft and made up of fat. The cartilaginous and bony joint bodies vary greatly in size, some being not larger than a bean or almond, while others are as large as the patella. Billroth states that a joint body has been preserved in the museum at Vienna as large as the os calcis, which was found attached by a pedicle to the capsule of the

joint. An important question is whether a perfectly free joint body can continue to grow. Virchow and others consider this possible through the taking up of fluid from the synovia and by proliferation of cartilage and marrow cells in the case of cartilaginous and bony joint bodies. In some cases, however, retrograde changes may predominate, and small bodies can be absorbed completely.

Symptomatology and Diagnosis of Free Joint Bodies.—As we stated before, joint bodies are found in joints which are either otherwise perfectly healthy or are the seat of chronic inflammation, particularly chronic hydarthros, arthritis deformans, and joint fractures that have not healed by bony union. Out of forty-five cases of loose bodies collected by Barth, severe symptoms of joint disease were present in thirty-nine. The disturbances either begin immediately after an injury or they develop very gradually in the course of years. The knee-joint is the most common location in which they are encountered, while of the other joints the elbow comes next. The symptoms caused by free joint bodies are, first of all, a sudden, severe, darting pain, experienced during some particular movement of the joint, often causing the patient to appear as though paralysed and to fall to the ground in a faint. These pains, which reappear with more or less frequency, are particularly likely to occur when a moderate-sized, freely movable joint body becomes caught in a synovial pouch or between the articular ends of the bones. The attacks of pain are usually followed by inflammatory manifestations in the joint of greater or less severity, which take the form of an acute serous synovitis.

Diagnosis.—These characteristic, paroxysmal pains are of the greatest importance for making the diagnosis of free joint bodies. In some instances the latter can be felt. Nevertheless, one can be deceived even in this, and I once mistook a commencing circumscribed tuberculosis of the capsule of the knee-joint for a free joint body. After opening the joint and extirpating the diseased portion of the capsule, recovery took place, with perfect motion in the joint. The most difficult cases to recognise are those in which the joint bodies exist in an articulation which has undergone changes due to arthritis deformans.

Treatment.—The best treatment for free joint bodies consists in their operative removal by aseptic arthrotomy. The body having been located by palpation, an incision is made directly down upon it, whereupon it is pressed through the opening thus made and the borders of the wound are immediately closed by sutures. The joint is then immobilised as completely as possible with an antiseptic protective dressing, over which splints are placed. If the patient is afraid of the knife, or if the condition does not cause him much trouble, we recom-

mend the wearing of an elastic cap around the joint, to afford the latter a certain amount of support and prevent too free motion. In those cases where the symptoms indicate beyond a doubt the presence of a joint body, but where, as in the elbow, it cannot be reached by an incision made directly down upon it, in case the patient's discomfort is great enough, the joint should be laid freely open with the strictest aseptic precautions, and, if necessary, a partial (temporary) resection undertaken to render it possible to remove the joint body.

Exostosis Bursata with Joint Bodies.—Bergmann operated upon an exostosis on the outer aspect of the lower end of the femur, just above the knee, which was surrounded by a capsule containing upwards of five hundred rice bodies made up of hyaline cartilage. The exostosis probably originated intra-articularly as an ecchondrosis of the articular cartilage, and derived a true synovial sac by pushing before it the capsule of the joint, the diverticulum thus formed becoming afterwards completely shut off from the joint. In other instances the exostosis has been found still in the joint, as in two cases of mine, where it was attached to the portion of the semilunar cartilage which adjoins the capsule. In these cases there were in addition two bodies lying free in the joint (see Exostoses, § 128).

§ 116. **Neuroses of Joints (Neuralgias of Joints; Nervous, Hysterical Diseases of Joints).**—The nervous or hysterical affections of joints, the neuroses or neuralgias of joints, were first described by the celebrated English surgeon Brodie, and his statements have been confirmed by such German surgeons as Stromeyer, Esmarch, and Erb; while quite recently Newton M. Shaffer has written an exhaustive treatise on the subject. No pathological changes can be made out in joints which are the seat of neuralgia. The knee and hip are the ones most commonly affected, and usually one joint at a time, rarely two or more. Females with an over-excitable nervous system, or who are markedly hysterical, especially young girls of the better classes of society, are particularly apt to suffer from these troubles, and hence the term *hysterical joint*. But the affection is occasionally met with even in perfectly healthy men and women. Among the exciting causes may be mentioned traumatisms, such as bruises and sprains of the joints, irritation of or pressure upon the nerves in the neighbourhood, excessive emotional disturbances, and taking cold. Joint neuralgias also occur reflexly from diseases of the abdominal viscera, especially the female sexual organs, and from diseases of the central nervous system, such as tabes.

Symptoms and Course of Joint Neuroses.—The chief symptom of a joint neuralgia or neurosis is the pronounced pain and tenderness in the joint, while objectively nothing abnormal can be made out. The pain is felt especially when pressure is made at some particular point, or when the joint is moved. In addition to these tender points, there

is generally a pronounced diffuse hyperæsthesia of the skin over the joint; but in rare instances there may be anæsthesia. Moreover, the function of the joint in question is disturbed—i. e., the patient avoids moving the joint because of the pain, and keeps it rigid. There are also observed a state of muscular spasm, with secondary distortions of the joints (contractures); vasomotor disturbances (urticaria-like wheals, alternate flushing and blanching, etc.); tremor; a marked feeling of weakness; atrophy of the extremity which is involved, and now and then paralyses. The stiffness and contractures of the joints, which may take the form of nervous club-foot or stiffness of the hip, will immediately disappear under chloroform anæsthesia, and while the patient is in this state the joint will be freely movable. The vertebral column, especially the spinous processes, are also sometimes tender on pressure. The course of the nervous joint affections is usually rather tedious and very variable. If the nervous system is otherwise normal, recovery generally takes place after the lapse of a longer or shorter time, though it may occur suddenly after some emotional excitement or after some energetic movements have been made with the joint. In cases of pronounced hysteria, or diseases of the nervous system, the patients are occasionally doomed to be confined to bed for years, and in such instances the affection is often incurable.

In making the diagnosis of a hysterical joint, we should note particularly that certain symptoms which indicate inflammation of the joint are absent, and that the contractures, the stiffness, etc., disappear completely under chloroform anæsthesia. The above-mentioned manifestations of the disease are so characteristic that they are generally sufficient to establish the diagnosis. Old sprains with slight intra-articular adhesions have sometimes been mistaken for joint neuralgias; but cases of this kind can be cured in a very short time by massage combined with forced movements of the joint.

The prognosis is favourable in the case of individuals who are otherwise healthy; but if they are excessively neurotic and hysterical, it is uncertain, and is the more unfavourable the more serious the nervous complications.

Treatment.—The treatment of nervous joint affections is directed first of all towards the cause. If there is pronounced neurasthenia, hysteria, or other nervous anomalies, or disease of certain organs (of the sexual organs, constipation, etc.), these conditions must receive careful attention. In every case a general tonic treatment for the nervous system by cold-water cures, sea-bathing, a sojourn in the mountains, and removal of the patient from his business and family, are very much to be recommended. Treatment of a psychical nature is also very valuable; while unexpected joy or sorrow has often caused hysterical joint neuroses to disappear suddenly and permanently. The local treatment of the diseased joint comprises massage and method-

ical exercise, rubbing with cold water, and electricity (the strong faradic or galvanic current passed transversely through the joint). Morphine or atropine is occasionally given in the form of hypodermic injections if the patient is otherwise healthy and robust. Quinine and arsenic, given internally, are also of use. For the contractures and the weakness of the muscles and joints we employ suitable braces or splints which will enable the patient to move his limbs.

Other Joint and Bone Neuralgias.—The neuralgias sometimes occurring in joints and bones which have previously been the seat of a disease like tubercular arthritis, or which make their appearance in the course of syphilis, or after recovery from caries and necrosis, or in general occur in old bone cicatrices, are of a totally different nature. Pain of this description is very apt to occur in syphilis, or in ossifying osteomyelitis and periostitis, or in sclerosis of bone. The treatment of these joint and bone neuralgias depends upon the cause. Warm baths and the bathing cures given at Teplitz, Wiesbaden, and Gastein are generally very useful. The pain occurring in bones and joints which have been at one time diseased may sometimes become so severe that amputation or disarticulation is performed at the patient's own request. Close examination of the bone in such cases reveals nothing which can account for the great suffering, but we do find that individuals thus affected are usually neurotic (Poncet, Auday).

Quite often, however, these neuralgias are due to circumscribed, inflammatory foci concealed in the bone or joint, and if this is the case the disease should receive its appropriate treatment. Abnormal adhesions in a joint, such as may occur, for example, in old dislocations which have been improperly treated, may give rise to violent pains, which can be quickly stopped by massage and exercise. In general, neuralgias of joints and bones following a pre-existing disease are most commonly the result of syphilis or some nervous disease; and these must be the first things to be considered in the treatment.

Sometimes violent pain also occurs in bones which are otherwise apparently healthy and have not previously been diseased, coming on especially after taking cold, and in neurotic individuals. Warm baths and the use of the above-mentioned hot springs, as well as an antineurotic treatment, should be employed.

§ 117. **Neuropathic Diseases of Bones and Joints.**—Peculiar neuropathic affections of the bones and joints, of great clinical interest, occur in the course of diseases of the nerves and spinal cord, especially tabes. Charcot was the first to describe accurately the arthropathies which make their appearance during the course of the grey degeneration of the posterior columns of the cord; and while Charcot, Erb, Buzzard, and other neurologists ascribe the arthropathia tabidorum to direct nervous influences—in other words, to trophoneurotic disturbances—Volkmann, Leyden, and Virchow maintain that the tabes merely brings about unfavourable conditions, in consequence of which

certain diseases of the joints occur more easily and frequently than they do in a state of health, and run an unusual and malignant course. The main predisposing causes in tabes of inflammations and injuries of the bones are the loss of sensibility—i. e., the anæsthesia or analgesia of the joints, the ataxia, and the fragility of the bones. These factors also influence very materially any deforming or traumatic, acute or chronic inflammation occurring in a person suffering from tabes dorsalis. The softness and brittleness of the bones in tabes are well known, and account for the frequency with which spontaneous fractures take place in patients with this disease. The fragility of the bones is due to a trophoneurotic change in their organic ground substance, and may be encountered even in bones which are apparently very strong and compact. The bones may also become remarkably brittle in people with various mental diseases, or with infantile spinal paralysis, progressive muscular atrophy, leprosy, etc., and Neumann has ascribed the changes that occur to an affection of the vasomotor system. Czerny, Rotter, and others have lately made exhaustive studies of arthropathia tabidorum and neuropathic bone and joint affections in general. The question of the relationship between these affections and the sclerosis of the posterior columns of the cord and other diseases of the spinal cord and peripheral nerves has recently been the subject of animated discussion, but as yet it has not been positively decided whether spinal diseases, such as tabes, syringomyelia, etc., should be regarded as direct causes of these troubles, which Charcot believes them to be, or only as predisposing. Charcot has lately adopted the view that they are due to certain localised processes of disease in the diaphyses and epiphyses.

Cause of Arthropathia Tabidorum.—As before stated, the anæsthesia or analgesia of the joints plays a most important part in the production and course of arthropathia tabidorum. The neuropathic affections of the joints which occur in tabes begin either without any external cause, or they follow the reception of some traumatism; and as the patients feel no pain, they walk about while their joints are inflamed and thus make matters worse; they wear off the brittle articular ends of the bones, as it were, so that the entire astragalus, for example, may by degrees completely disappear. A tabetic individual with a fracture of the leg, who came under my care, could produce a very marked displacement of the fragments without suffering any pain. The analgesia cannot always be easily recognised, it being occasionally limited to the more deeply situated nerves alone, while the skin is even oversensitive to the slightest irritation. The chronic arthropathies which occur in tabes and do not go on to suppuration, run, as a rule, a course

similar to arthritis deformans (see page 710), but differ from the latter in the fact that the different parts of the joints are very rapidly destroyed, and dislocations and spontaneous fractures are of frequent occurrence. One can distinguish, as in arthritis deformans, an atrophic and a hypertrophic form of arthropathies as well as a monarticular and a polyarticular form. If the specific excitants of inflammation—micro-organisms—gain entrance to a joint of this kind which is the seat of a chronic inflammation, septic or even gangrenous inflammation running a very rapid course ofter develops. Hence it can be seen that in the course of tabes various forms of arthritis may be encountered, some acute and others chronic, and either suppurative or non-suppurative; but the characteristic feature of the inflammation is that it is always greatly modified and influenced by the analgesia and ataxia which are present, and by the weakness and fragility of the bones. The knee is the joint most commonly affected, although the articulations of the upper extremity do not always escape. Rotter has collected 112 cases of joint disease occurring in 74 patients with tabes; of these, 49 were of the knee, 24 of the hip, 12 of the shoulder, 12 of the tarsal joints, 6 of the elbow, 4 of the ankle, 3 of the hand and fingers, and 2 of the temporo-maxillary joint. Both knee-joints were diseased in 11 cases, both hips in 7, the tarsal joints in 3, and the shoulder, wrist, and finger joints were symmetrically affected twice. In Weizsäcker's statistics of 109 cases, 72 occurred in men and 37 in women. The knee-joint was affected 78 times, the hip 31, the shoulder 21, the tarsus 13, the elbow 10, the ankle 9, the carpal and temporo-maxillary joints twice, and the vertebral column once. The observations of Leyden, Oppenheim, and others show that affections of the joints and weakness and fragility of the bones may occur in both the earliest and the most advanced stages of tabes dorsalis.

The *prognosis* of the tabetic arthropathies is very uncertain, and depends largely upon whether the joints are used or protected and properly treated, whether ataxia exists, etc. If proper treatment is received (fixation, orthopædic appliances, etc.), it is possible for the arthropathy to be improved or arrested.

Similar neuropathic affections of the bones and joints are also noted in the course of other cerebral and spinal diseases—e. g., acute and chronic myelitis—and are due to analogous disturbances of innervation. The arthropathies occurring in syringomyelia are particularly interesting. Neuropathic contractures are discussed on page 729.

The Arthropathies of Syringomyelia.—The arthropathies coming on in the course of syringomyelia mainly attack joints of the upper extremity, for the reason that the primary disease is for the most part localised in the cer-

vical portion of the spinal cord, and they occur in the great majority of instances in men of advanced age. Traumatisms play a predisposing part in their production. The course of the arthropathies is always chronic, not infrequently lasting for years. There will occasionally be observed an acute exudation in the joint, or even suppuration, especially if there has been some injury which on account of the analgesia has been neglected; but there seldom occurs such a marked destruction of the joint in a comparatively short time as in tabes. The changes in the joints are more like those of arthritis deformans, with the formation of intra-articular and periarticular osteophytes, with ossification of the periarticular soft parts, degeneration of the muscles, and thickening, dilatation, and relaxation of the capsule, with secondary spontaneous dislocations. The joints are analgesic, and sometimes to such a pronounced degree that large joints can be resected without chloroform (Czerny, Sokoloff). This analgesia is, moreover, the chief factor in furthering the development of the disturbances of nutrition which are present in the joints and bones. The bones are in some instances abnormally weak (hence the spontaneous fractures) and in others remarkably sclerotic. The termination of the arthropathies which occur in syringomyelia is governed mainly by the primary disease in the spinal cord, and also by the amount of care the patient takes to protect his joints from injuries that may readily give rise to complicating periarticular and intra-articular suppuration. Under favourable conditions the joint affections are usually very protracted. The diagnosis can be readily made if the pathological changes and the clinical course are taken into consideration together with the analgesia and the location of the arthropathies in the upper extremity. The treatment, particularly in the early stages, consists in immobilising the joint, though later on suitable operative measures may be necessary, as they are in tabes.

In making the *diagnosis* of neuropathic bone and joint affections, the characteristic features in chronic cases are the existing nervous disorders, which in the case of arthropathies of the lower extremity is most commonly tabes, and of the upper extremity syringomyelia, the analgesia, the pronounced exudation, and the marked destruction of the articular surfaces of the bones; the acute cases become rapidly worse. Czerny is right in calling attention to the fact that the predisposition to nervous disorders is an important matter from a medico-legal standpoint—in other words, should be taken into account in a plaintiff who brings suit for damages.

The *treatment* of the neuropathic inflammations of joints, particularly the arthropathies which occur in tabes and syringomyelia, comprises proper local treatment of the affected joint and general treatment of the neuropathy which is the primary cause of the trouble. We consider, as Czerny does, that firm anchylosis in a good position is preferable to a loose joint which is rapidly ground down by friction, and in the early stages it would be proper to bring about artificial anchylosis by performing arthrodesis (see page 139). If patients with the above-

mentioned diseases of the spinal cord receive a sprain, the joint must be treated by immobilisation and subsequently by a supporting apparatus. Should extensive destruction or suppuration of the joint occur, the question of arthrotomy, resection, or amputation would arise.

§ 118. **Anchylosis.**—By anchylosis (from ἄγκυλος, angular, crooked) is understood an immovable, stiff joint, such as results from an inflammation of a joint which has run its course. The word anchylosis signifies properly an angular position of the joint; but this conception of the term has in course of time been entirely given up, so that when we speak of anchylosis of a joint we mean that its power of motion has been lost, irrespective of whether the joint has become fixed at an angle or in a straight, extended position. If a joint is in an angular position we speak of it as a *contracture* (see § 119). Anchylosis—in other words, stiffness of the joint—and contracture very frequently occur in combination. If we wish to differentiate these two terms more exactly, we may say that *anchylosis* signifies a complete cessation of the motility of a joint brought about by intra-articular causes, while *contracture* is a limitation of motion generally due to pathological changes in the extra-articular soft parts (see all § 97 and § 98, Diseases of the Nerves and Muscles). We also recognise a false and a true anchylosis (anchylosis spuria and anchylosis vera). The term false anchylosis applies to those cases in which apparently immovable joints can be caused to move under chloroform anæsthesia, and is a condition which is observed in the course of acute or chronic inflammations of joints as a result of inflammatory or voluntary muscular contraction, or in hysterical joint disorders, etc.

The Causes of True Anchylosis.—True anchylosis is most commonly due to the development of a firm union between the different parts of the joint, and according to the nature of the tissue forming the union between these parts we recognise a connective tissue (anchylosis fibrosa), a cartilaginous (anchylosis cartilaginea), and a bony anchylosis (anchylosis ossea). The cicatricial connective tissue which develops between the opposed articular surfaces in the healing, for example, of an arthritis with fungous granulations, either takes the form of adhesions which resemble ligaments, or they more or less completely fill the joint. If ossification of the connective tissue takes place it is possible for a bony anchylosis to occur, in which case the articular ends of the bones are joined together by an osseous bridge, or united by bone throughout their entire extent. Bony anchylosis may develop from the cartilaginous form, or it may arise from the direct coalescence of joint surfaces which have lost their covering of cartilage. Cartilaginous anchylosis is brought about by a growth of vascular connective tissue between

the opposed surfaces of the articular cartilages, and if, then, this connective tissue disappears, the surfaces of the cartilage are found to have coalesced into a single cartilaginous mass. Other causes of stiffness in joints are cicatricial shrinkage of the capsule and ligaments of the joint, and adhesions between two opposed portions of the synovial membrane, so that the latter can no longer adapt itself to the movements of the different portions of the joint. Anchylosis may also be caused by proliferation of bone or cartilage in a joint, as in arthritis deformans, or by the development of bone in the capsule or parts surrounding the joint, which sometimes occurs after fractures in the neighbourhood of or extending into a joint. Furthermore, the articular ends of bones may be so altered by changes such as occur in caries and arthritis deformans that they do not fit together, and so are not capable of performing their function of gliding over each other (anchylosis of deformity). We learned in a previous chapter that joints may become fixed in a faulty position by muscular contractures, or by cicatricial processes in the muscles, tendons, tendon sheaths, bones, etc.

It is generally an easy matter to make the diagnosis of anchylosis, but in doubtful cases chloroform anæsthesia may be required to determine whether the anchylosis is false or true; it is also the best way of finding out how much motion, if any, exists.

Treatment of Anchylosis.—The treatment of a stiff joint includes both an attempt at restoration of its motion and at overcoming the abnormal position in which the joint may have become anchylosed; in other words, one should strive to place the joint in such a position that the limb may be more or less useful to the patient. Only in rare instances is it possible to restore motion in a joint which has become fixed by true anchylosis, and then it is generally accomplished by resection. But we can very often prevent an anchylosis from taking place by employing proper treatment for the diseases and injuries of the joints and the parts which surround them, particularly by causing wounds to heal aseptically, and after the subsidence of inflammation, by using massage and active and passive motion. If in the course of an injury or inflammation of a joint we are unable to prevent an anchylosis from developing, we must always place the joint in that position which will render it most useful for the patient—the knee, for example, in extension, the ankle and elbow at a right angle, etc. If the joint has already become fixed in a distorted position, it may be possible to gradually overcome the latter by massage and passive motion, by manual correction under anæsthesia, by permanent extension by a weight, by the use of frequently applied plaster-of-Paris dressings or splints which exert pressure or traction, or by operative

division of the contracted periarticular soft parts, especially the muscles, tendons, and fascia (see Tenotomy, Myotomy, page 580), by osteotomy of the bone in the neighbourhood of the joint, or by resection of the joint, combined possibly with the removal of a wedge of bone. Osteotomy is performed either in the form of simple division of the bone (see § 26), or division combined with the removal of a wedge-shaped piece from the continuity of the bone. Volkmann's method of performing linear or wedge-shaped osteotomy below the trochanter of a hip which has become anchylosed has yielded excellent results, improving both the position and the usefulness of this joint. In some cases the joint is opened (arthrotomy), and all the intra-articular and periarticular adhesions and bands which prevent the movements of the joint are divided (arthrolysis—Wolff), without resection of the articular ends. Resection of the joint (§ 40), and in desperate cases amputation or disarticulation (§ 36 and § 37), are also operations which may have to be resorted to. When there is a firm anchylosis due to fibrous, cartilaginous, or bony union between the articular ends of the bones, combined with a contracted position of the joint, arthrolysis or resection are generally called for, the object being the formation of a movable joint, or one fixed in a position which will render use of the limb possible. In order to prevent a recurrence of the anchylosis a celluloid plate or an absorbable membrane of animal tissue (hog's bladder) may be inserted between the joint surfaces. The operation of arthrodesis for obtaining artificially anchylosis of a paralytic, flail-like joint is described in § 40.

§ 119. **Deformities of Joints (Contractures).**—The deformities of joints which we shall speak of here are faulty positions in which joints may have become more or less fixed, and are sometimes congenital and sometimes acquired, and when acquired are called contractures. In discussing the subjects of inflammation and anchylosis of joints we learned how contractures might develop, and consequently we shall confine ourselves at present merely to a brief account of the individual forms of this affection, the reader being referred to the Regional Surgery for a more detailed description of each, especially as regards the treatment.

Fig. 448.—Club-foot (pes varus).

The *congenital* deformities of joints are mainly due to disturbances of development which occur in the fœtal stage of life. The congenital club-foot (pes varus, Fig. 448)—i. e., the supination-contracture of the foot—is an

le of this. The supination is almost always combined with : flexion (pes equino-varus). It might be said that a slight t of club-foot is physiological, inas- as every infant at birth has some tion of it. Pronounced club-foot is, speaking, a disturbance of develop- n the astragalo-crural, the calcaneo- ıloid, or the astragalo-scaphoid joints, is brought about principally by the eing kept in continuous supination to lack of space in the uterus. The hich undergoes the most pronounced : of form in consequence of this ıal supination of the foot *in utero* astragalus, the neck of which be- longer than it normally should be, mewhat bent; in other words, the growth of the as- tragalus adapts itself to the abnormal position which the foot assumes *in utero*. The rare cases of congenital flat-foot (pes valgus or planus, Fig. 452) and of pes cal- caneo-valgus originate in a similar manner, being due to the pressure exerted by the walls of the uterus. By pes calcaneo-valgus is understood a foot which is dorsally flexed to such an extent that its dorsum comes nearly or quite in contact with the leg, and is at the same time abducted (Fig. 455). Scoliotic or kyphotic curvatures of the spinal column, or club-hand or club-foot, may also have their origin in congenital defects occurring in the vertebræ or in the bones of the forearm or (lower) leg (see Fig. 449).

FIG. 449.—Club-foot caused by a congenital absence of the entire tibia.

450.—Scoliosis.

The *acquired* deformities of joints are due first of all to disturbances occurring during the growth of articular surfaces previously normal, in children and young subjects. Thus deformi- ties of the joints develop in the lower extremities and vertebral column as a result of the pressure l by the weight of the body. Their origin is to be ascribed to ·e on the joint surfaces, which is either too protracted or too ve, or unevenly distributed. This class of cases includes the

lateral curvatures of the spinal column or scoliosis (Fig. 450 valgum (Fig. 451), and flat-foot (pes planus or pes valgus, Fi Rhachitic bones are particularly apt to suffer from these pres formities; the pressure causes ual change in the shape of th their growth being diminishe parts where the pressure is and increased where the pr least. The diaphyses or ep of the long hollow bones, es if they are soft (see Rhachi thus bent and curved by the which they have to sustain is also the explanation of the in the shape of the vertel countered in a case of scoliosi has existed for a long time the curvatures of the fem tibia in the neighbourhood junction of the epiphysis w diaphysis; of the obliquity condyles in genu valgum (Mikulicz); and of the depression of t of the foot and change in shape of the tarsal bones in pes Stretching or shortening of the soft parts, especially the muscles and the ligaments of the joint, may then develop secondarily. has recently combated the above theory of the mode of devel of bone deformities, viz., through pressure. According to him, the deformities of bones are to be regarded as an adaptation to a pathologically altered function; the changes in the external form of the bones are a result of their internal structure. As opposed to the pressure theory, the parts that are the seat of pressure show an increased growth of bone corresponding to the "trophic stimulation of function"—i. e., the bony tissue is here thickened, while on the side that is free from pressure it is r I consider these views correct.

Fig. 451.—Genu valgum.

Fig. 452.—Pes valgus

As a result of primary disease of the muscles, or, more com of the nervous system, myopathic and neuropathic deformities

other words, true contractures of joints, are produced. Primary muscular contractures used to be thought very common, and were wrongly looked upon as the cause of scoliosis and flat-foot.

Neuropathic contractures are divided into the spastic and the paralytic. Spastic contractures are the result of diseases of the central nervous system, and hence belong more properly to the province of internal medicine, so that we shall confine ourselves here to merely a brief description of them in so far as they are of surgical importance. Little and Erb have recently made a special study of this form of contracture, and have shown that it is not by any means as rare as has hitherto been supposed.

Fig. 453.—Spastic contracture of the lower extremities.

Spastic Contractures—Spastic Spinal Paralysis.—Spastic contractures are observed most commonly in the course of spastic spinal paralysis, a condition which is characterised by spasm of the muscles and increased reflexes, and is caused mainly by chronic inflammation (sclerosis) of the lateral pyramidal tracts (Charcot, Erb). The autopsies, however, have not shown a pure primary degeneration confined to the lateral tracts, and it is hence doubtful whether the spastic spinal paralysis is really a disease *sui generis*—i. e., a primary degeneration of the lateral pyramidal tracts. It occurs as a symptom in various affections of the central nervous system—e. g., in chronic hydrocephalus, cerebral focal diseases with secondary degeneration of the lateral tracts, hydromyelus, slight compression of the cord above the lumbar enlargement, spinal meningitis, after sprains of the cervical vertebræ, hysteria, etc. Among etiological factors, syphilis, injuries of the spine, heredity, etc., are important. The disease occurs most commonly in adults from twenty to fifty years of age, but it has been observed in children, and even as a congenital affection in adults.

Fig. 454.—Pes equinus paralyticus.

The symptoms are as follows: At the outset there are observed a slight fatigue and motor weakness of the lower extremities, which become affected

simultaneously or one after the other; in rare cases the disease begins in the arms. The legs gradually become paralysed. It is characteristic that the muscles do not become atrophied, and that marked symptoms of motor irritation and muscular spasms going on to tetanic contractures make their appearance early. The tendon reflexes are very much increased, the skin reflexes remain normal, sensory and trophic disturbances are slight or absent, the functions of the bladder and rectum are unchanged, and ataxia never develops.

Fig. 455.—Pes calcaneus paralyticus.

The spastic gait caused by the muscular contractures is very characteristic. The legs are pressed against one another, the patient drags them after him, the ends of the feet hang downward and are used as a support, the body is bent forward sharply, and there is a marked tendency to stumble and fall. In consequence of the spasm of the muscles the tendons are lengthened, and the bone is sometimes thickened at the point of insertion of the tendons. Fig. 453 represents a severe case. The spastic contractures are more marked in the legs than in the arms. The paralysis gradually spreads upward (paralysis and rigidity of the muscles of the back, abdomen, and arms). The course is very chronic. The prognosis is favourable as far as life is concerned, as the vital functions are not interfered with, but the disease is usually incurable, although it may become stationary and even improve considerably. The treatment includes the use of galvanism, hydrotherapy, prolonged baths at 26° C. (78° F.), and, above all, orthopædic treatment to make walking possible. The orthopædic treatment consists in straightening out the contractures under an anæsthetic, tenotomy of certain tendons, followed by the application of plaster splints, and the use of orthopædic appliances for practising certain movements. Massage is also employed. Tenotomy not only aids in straightening the limb, but it also has an antispasmodic effect. Internally, silver nitrate, ergotin, potassium iodide, and bromides are given. The possibility of syphilis or a previous traumatism should always be borne in mind.

Fig. 456.—"Claw position" (main *en griffe*) of the fingers following paralysis of the ulnar nerve.

Paralytic Contractures. — The paralytic contractures—i. e., those which are the result of paralytic conditions and follow injuries and diseases of the central nervous system and peripheral nerves—are extremely common (see Figs. 454, 455, 456). They include the paralytic contractures which occur so frequently with the partial or total paralyses following menin-

gitis and encephalitis in children, and the spinal (so-called essential) infantile paralyses which affect almost exclusively the lower extremity. Of the paralytic contractures of the foot the most common are the pes equinus paralyticus (Fig. 454) and the paralytic club-foot which very often takes the form of pes equino-varus paralyticus. In the paralytic club-foot the equinus position predominates, but in the congenital form the varus contracture—i. e., the adduction and supination—is the most noticeable feature (Fig. 448). The pes calcaneus paralyticus (Fig. 455) and the pes valgus paralyticus (Fig. 452) are much rarer. Paralytic contractures of the knee, the hip, and especially of the hand, where they may follow injuries of the ulnar, median, or musculo-spiral nerves, are comparatively common. Fig. 456 illustrates the typical *main en griffe*, or claw position, assumed by the fingers after paralysis of the ulnar nerve. In the region of the spinal column paralytic contractures take the form of lateral curvatures (paralytic scoliosis) or of flexion or extension contractures (paralytic kyphosis and lordosis). In all cases paralysis of any one particular group of muscles, or rather of the nerves which supply them, invariably gives rise to a characteristic contracture (see Regional Surgery, § 294).

Infantile Spinal Paralysis.—As the spinal paralysis of children often leads to paralytic contractures, it should be briefly described at this point. The disease usually attacks children between one and four years of age. The acute infectious diseases and rheumatism have an important etiological bearing upon it, and heredity is sometimes to be taken into consideration. Pathologically it is an acute inflammatory process situated in the anterior grey horns of the spinal cord (poliomyelitis acuta), and is most commonly located in the lumbar, less often in the cervical, enlargement; it is either unilateral or bilateral, and is characterised by hyperæmia, by hæmorrhages, and by red softening with degeneration of the ganglion cells and nerve fibres. This inflammatory process, which at the outset is acute, results in the development of a circumscribed or diffuse sclerosis (connective-tissue growth) with secondary atrophy of the nerve fibres, and a subsequent secondary descending degeneration of the nerves. The muscles supplied by these nerves likewise undergo a degenerative atrophy, and in addition become the seat of a secondary interstitial growth of connective tissue or fat. The atrophy of the nerves and their roots is a secondary change, and that of the muscles is a result of the loss of their trophic centres in the anterior columns of grey matter. Leyden states that the affection may also result from a peripheral multiple neuritis, the latter in part remaining peripheral and in part leading to localised disease of the spinal cord.

I must refer the reader to the text-books on nervous diseases for a full description of the symptomatology of infantile spinal paralysis, as only the following brief outline will be given here. The disease usually begins suddenly without prodromata, with a high fever, 40° to 41° C. (104° to 105.8° F.), and corresponding acute manifestations accompanied by stupor, convulsions, etc. Occasionally this acute febrile onset is absent. After one or two days the acute manifestations generally disappear. The paralysis develops during the time that the temperature is elevated, but is usually not noticed till later. It spreads at first very rapidly, and may affect all the muscles of the limbs and even those of the trunk. It then ordinarily diminishes, leaving a permanent paralysis which varies greatly in extent, but is generally monoplegic and confined to one leg, less often paraplegic, and still more infrequently takes the form of spinal hemiplegia or of crossed spinal hemiplegia (leg and arm of different sides). Often only parts of a limb, or, more exactly, only certain groups of muscles, are affected. The permanent paralysis is purely motor, and is characterised by a rapidly progressing atrophy of the muscles. Within one or two weeks the faradic excitability is lost, though at the outset there is a temporary increased response to the galvanic current, especially to the positive pole. There are to be noted, in addition to the reaction of degeneration, the absence of the cutaneous and tendon reflexes in the region where the muscles are paralysed, the not uncommon hyperalgesia of the latter on pressure and their steadily increasing atrophy, and, above all, the previously mentioned contractures which most frequently occur in the foot. The treatment is given on page 735.

Infantile Cerebral Paralysis (*Spastic Hemiplegia, Acute Poliencephalitis*—Strümpell).—Infantile cerebral paralysis, which occurs chiefly in children from three to four years of age, is caused by lesions in the motor areas of the cortex (inflammatory changes with atrophy, loss of tissue, cicatrices). There is sometimes a diffuse sclerosis of the cortex, atrophy of one hemisphere, etc. The disease is also congenital, or may be due to conditions occurring during birth. The same etiological factors are present as in infantile spinal paralysis. The onset of the disease is acute, with fever and convulsions, vomiting, and usually unconsciousness. The duration of this initial stage varies from days to months. Later the constitutional disturbances disappear and the paralysis becomes noticeable. The latter is generally confined to one half of the body (with exception usually of the face), to an arm or leg. Sometimes true paralyses are not present, but only a slight limitation of motion. The following symptoms are characteristic of cerebral paralysis: The faradic contractility of the paralysed muscles is unchanged, there is no reaction of degeneration, the sensation and temperature of the skin are usually normal, and the tendon reflexes are increased, particularly on the paralysed side. Contractures of the paralysed muscles usually appear early.

There are also evidences of irritation of the motor centres (athetosis, severe twitching), and cortical epilepsy, either in the form of a local spasm of the paralysed muscles without loss of consciousness, or a true epileptic attack; in the latter case the convulsions begin in the paralysed muscles and then become general. Mention should also be made of the marked disturbances in the growth of the muscles and bones on the paralysed side. In some cases there are mental disturbances, paralysis of the bladder, rectum, etc.

The treatment is in the main the same as that of infantile spinal paralysis, and is principally orthopædic (see page 735).

The Manner in which Contractures Develop.—How do the various paralytic contractures which occur in such typical forms come to take place? Delpech was of the opinion that they were produced by active shortening of the non-paralysed antagonistic groups of muscles, and that for this reason the contracture took place towards the side of the antagonists. But Volkmann and Hueter have shown that this antagonistic theory is not in itself sufficient to explain the manner in which paralytic contractures develop; that, in fact, the contracture of the antagonists is quite commonly absent, and that, in addition, the contracture really forms in the direction of the paralysed group. They proved that the weight of the limb, and, in the case of the lower extremity, the superimposed weight of the body, play very important parts in the production of the paralytic contractures. This is the way in which the pes equinus paralyticus (Fig. 454) develops, since the foot drops down of its own weight—in other words, assumes a position in plantar flexion, no matter whether all the muscles of the leg below the knee or only the extensors are paralysed. This equinus position of the foot may also result from a paralysis which is limited to the muscles of the calf alone, for the reason that the paralysed muscles undergo a shortening from lack of nutrition. The weight of the paralysed limb can likewise be shown to have an effect upon the development of contractures in other joints of the upper and lower extremity.

The pressure exerted upon the paralysed part by the weight of the body is a matter of importance in the production of the various contractures which may occur in the spinal column and in the lower extremity when the affected limb is used for standing and walking. This partially explains the way in which the paralytic scoliosis and paralytic flat-foot develop. The rare deformity known as pes calcaneus (Fig. 455), which is usually combined with a valgus position—i. e., a flattening of the inner border of the foot—is, according to Volkmann, caused by a tipping forward of the os calcis, due to the latter not being held firmly enough in position by the muscles of the calf.

The diagnosis of paralytic contractures is usually easy, and can be made from their general appearance, without an electrical exam-

ination (see Injuries of Nerves, Diseases of Nerves, § 87, § 88, and § 97).

The pure myopathic contractures due to primary disease of muscles are much rarer than the neuropathic, and result from certain forms of atrophy, injury, and inflammation of muscle (see § 98).

The cicatricial contractures, especially those due to loss of substance in the skin and subcutaneous soft parts following acute and chronic inflammations of the soft parts and joints, have already been sufficiently described in the chapters on Healing of Wounds (§ 61) and on Injuries and Inflammations of the Soft Parts (§§ 87–100).

We have thus gained an understanding of the numerous causes which give rise to contractures, and can now distinguish two main groups of those which involve joints, basing the classification upon the

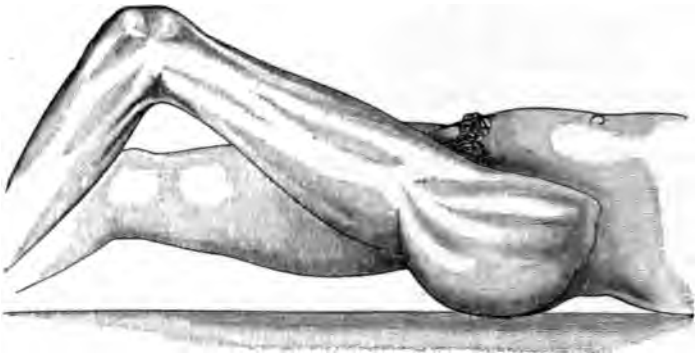

Fig. 457.—Contracture of the hip-joint in coxitis from shrinkage of the fascia lata.

manner in which they originate; these are, (1) *arthrogenic* contractures resulting from congenital or acquired changes in the parts which constitute the joint, and (2) *non-arthrogenic* contractures due to pathological changes in the neighbourhood of the joint, or to other diseases, especially those of the nervous system. The neurogenic, myogenic, and tendogenic contractures which follow diseases or injuries of the nerves, muscles, or tendons, or are brought about by shrinkage of fascia, etc., belong to the non-arthrogenic class. The cicatricial contractures which follow losses of substance from traumatism or inflammation, or are the result of adhesions, may occur in any part of the body. Contractures of joints are sometimes produced by causes which are partly arthrogenic and partly non-arthrogenic, as, for example, in chronic inflammations of the hip (coxitis), where there develops along with the inflammation a progressive shrinkage of the fascia lata, unless this is prevented by proper treatment (Fig. 457). Muscular contrac-

tures in diseases of joints are also very frequently caused by reflex action, as described on pages 569 and 575.

Treatment of Deformities and Contractures of Joints.—The treatment of very many of the deformities and contractures of joints belongs really to the province of orthopædic surgery, which has made great progress in the last few years. It would require too much space to describe at length the treatment of each separate deformity, but it will suffice to say here that in general the treatment consists in the use of immobilising dressings (plaster of Paris, extension), supporting apparatus, operative measures (osteotomy, tenotomy, myotomy), electricity, massage, and gymnastics. The treatment of cicatricial contractures which have resulted from inflammation and injury of the soft parts has already been spoken of in connection with Injuries and Inflammations of the Soft Parts (§§ 87–100), and the treatment of arthrogenic contractures has been given in connection with Inflammations and Anchylosis of Joints (§§ 113–118).

The treatment of infantile spinal paralysis consists in the use of massage, electricity, and a strengthening mode of life. A weak galvanic current should be applied to the spinal cord as early as possible, by placing one of the large flat electrodes over the portion which is supposed to be the seat of the disease, and the other electrode on the anterior surface of the trunk, and then alternating the action of the anode with that of the cathode. In addition, the muscles themselves are treated with weak faradic or galvanic currents, and massaged, or rubbed with alcohol. Baths (hot baths, salt baths, sea baths, etc.) are useful, as well as other hydrotherapeutic measures; also the internal administration of the iodide of potassium, nitrate of silver, ergotine, iron, strychnine, cod-liver oil, and finally good air and nourishing food. Supporting apparatus or immobilising dressings should be used to prevent the occurrence of deformities, especially in the lower extremities. In suitable cases (e. g., in paralytic pes valgus, pes equinus, etc.) the transplantation of tendons is employed; the paralysed muscles or tendons are sutured into non-paralysed ones, and the function of the former is thus restored. See also page 481 and the Regional Surgery.

The treatment of infantile cerebral paralysis is in the main the same as that of the spinal form.

The treatment of spastic spinal paralysis has already been spoken of on page 730.

In order to prevent or correct deformities, it is a good plan to use plaster-of-Paris dressings or suitable orthopædic contrivances. Tenotomy is often of great value; it not only corrects deformity, but acts directly as an antispasmodic measure.

§ 120. **Injuries of Joints.**—Injuries of joints are divisible into two main groups, (1) subcutaneous and (2) open. The latter are also called penetrating, as they enter the joint-cavity. We shall first take up contusions of joints.

Joint Contusions.—Contusions resulting from a blow with some blunt instrument, or from a fall, are the mildest form of injury to a joint. The contusions may be direct or indirect, depending upon whether the violence which causes the injury acts directly upon the joint, or indirectly by *contre coup*. Indirect contusions of the hip, for example, are caused by a fall upon the feet or upon the trochanter. In indirect contusions the principal injury is a greater or less amount of bruising of the articular surfaces brought about by the latter being forced against one another, and in the worst cases a fracture may occur with impaction of the fragments; but in direct contusions it is mainly the surrounding soft parts and the synovial membrane which are injured.

The most important symptom of a contusion of a joint is the effusion of blood into the latter—the hæmarthros—which is in some cases slight, in others very marked, so that the joint feels tense. The blood coagulates in a joint very quickly, but the clots soon diminish in amount—i. e., they are, as it were, dissolved by the synovial fluid, so that in twenty-four hours after the accident there is a viscid, bloody collection in the joint, which is readily absorbable by the lymphatics of the synovial membrane (Jaffe). If the joint is filled to its utmost limits it becomes slightly flexed, as this position renders it most relaxed and gives it its greatest capacity. The effusion of blood is, of course, most easily made out in joints like the knee, which are superficially situated. In hæmophilia and scurvy an effusion sometimes occurs spontaneously, or as a result of very slight injuries. Other symptoms of joint contusions are an infiltration of the skin and the subcutaneous soft parts with blood, especially if the contusion is direct; pain in the joint, which is usually slight, but made worse by movement; and disturbance of function, varying with the amount of blood which is effused. For the symptoms caused by a fracture of the bony parts of a joint the reader is referred to § 101 (Fractures).

The subsequent course of a contusion of a joint which is not complicated by a fracture is, as a rule, favourable, and complete recovery usually follows in a short time, though occasionally slight inflammatory symptoms, or hydarthros, persist for a good while. It is only in very exceptional instances that suppuration takes place within the joint, from a suppurative process which originates in a laceration of the skin, gradually extends to the deeper parts, and finally involves the articula-

tion. Suppuration of the effusion of blood, due to micro-organisms which are deposited by the circulating blood, is extremely rare, but in a tubercular or scrofulous person a tubercular inflammation not infrequently results from a contusion or sprain of a joint.

The diagnosis of contusion can usually be easily made from the swelling of the joint coming on after a traumatism, from the fluctuation, the pain on movement, and the more or less marked loss of function. The effusion, if sufficient in amount, assumes the outward configuration of the joint. The possibility of hæmophilia, as well as of fracture, should always be thought of, and as careful an examination as possible made with these in view.

The treatment of joint contusions consists in the employment of massage at an early period, in order to get rid of the effusion by pressing it into the interstices between the tissues and by causing it to be absorbed by the lymphatics. Pressure applied to the joint by means of elastic bandages, and, above all, repeated movements of the joint, also promote the absorption of the blood. In this way joint contusions are made to get well very rapidly, and even very large effusions will disappear in a few days if massage is begun as soon as possible after the accident. Contusions of joints used to be treated by keeping the joint at rest and by applying ice. Ice is seldom necessary, and then only in the first stages, to soothe the pain; but keeping the joint at rest is actually harmful in typical cases uncomplicated by a fracture, as the organisation of the effusion into connective tissue is thus materially helped. Puncture and antiseptic irrigation of the joint (see page 692) are only necessary when the joint is distended to its utmost capacity. For the treatment of a hydarthros or suppuration of a joint which may follow a contusion, the reader is referred to §§ 113, 114. A subcutaneous fracture within a joint is treated according to the rules laid down on page 621.

§ 121. **Sprains** (*Distortions*).—By a sprain or distortion we mean a momentary forcible stretching and twisting of a joint, usually combined with a laceration of certain portions of its capsule and ligaments. At present we shall omit all mention of the severe, complicated lacerations which are accompanied by opening of the interior of the joint, as we shall return to these injuries under the subject of Penetrating Wounds of Joints, and shall confine ourselves here simply to a description of the typical subcutaneous sprains or distortions which occur with such great frequency.

Besides the stretching and tearing of the capsule and ligaments of the joint and the periarticular soft parts which we have just mentioned, there also occurs a temporary change in the normal position of the articular ends of the bones—a momentary partial dislocation, as it

were—but as soon as the force has ceased to act they return to their proper position. Sprains are usually caused by the same sort of violence as dislocations (see § 122)—i. e., by forced movements which are carried beyond the physiological limits, or which are at variance with the normal mechanism of the joint. The amount of force applied in causing sprains is, however, not sufficient to bring about a more than temporary separation of the articular ends of the bones, and only a stretching or partial tearing of the capsule and ligaments takes place, though in the severest cases these structures may be completely ruptured. Sprains of the wrist are usually the result of hyperextension, hyperflexion, or torsion of the hand, and those of the ankle of forced pronation or supination of the foot. Simultaneously with sprains of the joint the neighbouring muscles and tendons are of course often stretched and lacerated, but a partial or complete rupture of the muscles and tendons or dislocation of the latter is only observed in rare instances. Injuries of bones, consisting in contusions of their articular ends, or in tearing or chipping off portions of them, are common occurrences in distortions. Examples of such injuries are fractures of the fibula or internal malleolus in sprains of the ankle, fractures of the lower end of the radius in sprains of the wrist, and cortical tear-fractures (*Riss-fracturen*)—i. e., the tearing away of pieces of bone which form the points of insertion of ligaments and tendons. I should not omit mentioning the dislocations of interarticular cartilages which may take place—the semilunar fibro-cartilages of the knee, for example—in sprains of the latter joint.

The symptoms of a sprain consist mostly in a very intense pain, in consequence of which the active function of the joint is disturbed, the joint becoming completely powerless and as though paralysed. There is usually a diffuse swelling of the joint, caused by the intra-articular and periarticular effusion of blood, and if a fracture is present at the same time this effusion is very marked. Later, owing to changes in the colouring matter of the blood situated in the skin and subcutaneous tissue, bluish-red, bluish-green, dark yellow or yellow discolorations make their appearance. The subsequent course of sprains in typical cases is usually favourable, and as a rule, if proper treatment is adopted, they get well very rapidly. In cases complicated by a fracture, the final outcome, especially as regards restoration of the function of the joint, is dependent upon the nature and location of the break in the bone. Complicated cases of sprain may occasionally give rise to chronic deforming inflammations of the joint, which obstinately resist every form of treatment. In other instances anchylosis may develop, or the opposite conditions may be encountered, the articulation becom-

ing loose and flail-like from the stretching and displacement of its various constituents, so that subluxations, or partial dislocations of joints, like the wrist, knee (genu valgum), or ankle (flat-foot), may result. The consequences which may ensue from an unrecognised rupture of a tendon or separation of the latter from its point of attachment are also worthy of consideration. Sprains, like contusions, are only followed by acute suppuration of the joint in very exceptional instances; but not infrequently predisposed individuals may subsequently acquire a tubercular arthritis in a joint which has been the seat of a distortion.

The *diagnosis* of sprains can be easily made from what has been said; but the joint should always be carefully examined for fracture, especially when the injury is near the hand or foot.

The *treatment* of subcutaneous sprains which are not complicated by a fracture is essentially the same as that of a contusion of a joint, and consists in early massage, intermittent bandaging of the joint with an elastic bandage, and the use of methodical movements. Antiphlogesis is very frequently not necessary, or at most only in the first few hours or days. Massage, in cases not complicated by a fracture, frequently seems to act in a marvellous way, and a joint which is still perfectly stiff and without function may again be made capable of active motion and of performing all its functions by massaging it only once. The sooner massage is begun the better. Rest and immobilisation in uncomplicated cases are to be condemned. If a fracture is present, it should of course be treated according to the general principles which apply to it. In the rare cases of complete rupture of the tendons or capsule, the joint must likewise at first be immobilised until the tears in these structures have united. If tendons have been ruptured, their ends may ultimately have to be joined together by catgut sutures. Other complications, such as suppurative arthritis—which very rarely occurs—are to be treated in the usual way. Puncture and antiseptic irrigation of the joint, on account of extreme distention of the latter with blood, are called for only in exceptional instances.

§ 122. **Dislocations (Luxations) of Joints.**—By a dislocation is meant a permanent displacement of the articular ends of two or more of the bones making up the joint. Dislocations are complete or incomplete, the latter also being called subluxations. In *complete* dislocations the opposed joint surfaces are entirely separated from one another, while in the *incomplete* variety the articular ends are still partially in contact. The dislocations of amphiarthroses like the symphysis pubis are usually called diastases. A distinction is also made between recent and old, and between simple and complicated or compound disloca-

tions. The latter include those especially which are associated with open wounds in the soft parts, with ruptures of large vessels or nerves, or with fractures.

As regards the causation of dislocations, we distinguish (1) the traumatic, due to external violence, (2) the spontaneous, pathological, or inflammatory dislocations which occur in the course of an inflammation in a joint, and (3) the congenital dislocations.

I. **Traumatic Dislocations.**—Traumatic dislocations are almost always the result of external violence, rarely of excessive muscular action. The force is usually applied indirectly, so that the bones are separated from one another by leverage, the power being exerted at a greater or less distance from the joint. Thus, as a rule, forced movements are caused to take place which go beyond the physiological limits of flexion, extension, abduction, adduction, pronation, or supination, or movements are produced which are at variance with the normal mechanism of the joint, particularly forced rotation. In every joint there exists a mechanism for checking its motion; this is generally made up of bone, less often of the ligaments or capsule of the articulation. When a dislocation takes place this natural inhibitory mechanism is overcome, and the articular end of the bone is pressed against this check to its further movement, which then becomes the fulcrum. If the force ceases to act at this stage, the articular ends of the bones return to their normal position of contact with one another, and only a sprain is the result; but if the force keeps on acting, one of the articular surfaces is lifted from the other, the capsule ruptures, the ligaments and muscular insertions which resist are stretched or likewise ruptured, and the articular end of the bone escapes either partially or completely from the capsule.

In a dislocation of the elbow from over-extension, the olecranon fossa acts as the fulcrum against which presses the tip of the olecranon process. At the hip the rim of the acetabulum is the fulcrum. The point where the displaced articular end of the bone finally comes to rest depends upon the nature of the movement and the amount of force brought to bear. After the force which produces the injury has ceased to act, the dislocated articular end of the bone is made to assume some particular position by a so-called *secondary movement*, brought about by the elasticity of the soft parts —skin, ligaments, capsule, and muscles. In this the weight of the limb and the movements made by the injured person or by others are also to be taken into consideration. The dislocated articular end of the bone is held in its new position mainly by means of the uninjured portions of the capsule and accessory ligaments. The disloca-

tions caused by direct violence, such as a blow or fall upon the joint, are much rarer.

Occasionally dislocations result from muscular action, especially at the shoulder (Cooper, Streubel, etc.), where they have been caused by making attempts to seize an object placed above the head, or by pulling with the hand elevated. The dislocations of the lower jaw due to opening the mouth too wide, as in yawning, are also produced by muscular action; and dislocations following general muscular contractions, as in epilepsy or eclampsia, belong to the same category.

Many persons can dislocate their joints voluntarily; but these dislocations—that of the first phalanx of the thumb being a common example—are not ordinarily complete, though in some instances they may be. The well-known athlete Warren was able at will to completely dislocate most of his joints, including the shoulder and hip, and, in the case of the latter, to cause the head of the femur to lie two inches above Nélaton's line. Then, when he wished, he could reduce it again, causing a loud, snapping sound. Acrobats and so-called "snake men" bring about by constant practice such a lengthening and loosening of the capsule and ligaments of their joints that they can finally dislocate the latter and bring them back into place again voluntarily.

Occurrence of Traumatic Dislocations.—Dislocations are most common in middle life, and are very rare in old people and young children, for the reason that external violence is more likely to cause their bones to break. Young children are very apt to sustain separations of the epiphyses owing to the slight powers of resistance which the latter possess. Dislocations of the upper extremity are the most common, amounting, according to Krönlein, to 92.3 per cent. of all luxations, while dislocations of the lower extremity amount to only 5 per cent., and those of the trunk to only 2.8 per cent. Dislocations of the shoulder, on account of the freedom of motion in this joint, are the most common, constituting about one half of all the dislocations which are encountered (51.7 per cent., Krönlein). Dislocations occur from three to five times more frequently in men than in women, because the former are more exposed to injuries on account of their occupations. Dislocations of the lower jaw are, however, according to Krönlein, about four times more common in women than they are in men.

The anatomical changes—i. e., the amount of injury to the tissues—depend in general upon the nature and intensity of the force which is brought to bear and the anatomical structure of the joint in question. As a rule, however, the following injuries to the tissues are more or less constant: The rent in the capsule, which is always present in a complete traumatic dislocation, is sometimes slit-shaped and sometimes irregular in form; not infrequently the capsule is torn from its insertion, and may or may not carry with it at the same time a portion of the bone to which it is attached. The accessory ligaments are either stretched, lacerated, completely ruptured, or

torn from their point of insertion on the bone. Similar changes take place in the muscles. The intra-articular and periarticular effusion of blood is usually not very large, and when it is, a fracture may be suspected. The most important complications of traumatic dislocations are extensive injury to the skin and subcutaneous soft parts, the simultaneous presence of a fracture, and injuries to large vessels, nerves, and internal organs.

Fig. 458.—Luxatio femoris supracotyloidea inveterata with a perfectly formed new acetabulum (preparation from the collection in the surgical clinic at Bonn—Krönlein).

In the majority of cases of uncomplicated dislocations, after reduction of the displaced articular surfaces has been accomplished, a complete *restitutio ad integrum* usually follows, the rent in the capsule appearing to heal with especial rapidity. But if the dislocated articular end of the bone remains in its abnormal position a new more or less perfect joint is formed—a so-called nearthrosis (see Figs. 458, 447). These nearthroses are sometimes very perfectly developed, especially at the hip and shoulder. As illustrated in Fig. 458, a new socket is formed at the hip by growth of the periosteum, which becomes covered with hyaline or fibrous cartilage. The capsule is constructed by an inflammatory new formation of tissue in the surrounding soft parts, and its inner surface is gradually made smooth by the movements of the head of the bone, so that it may finally come to resemble a synovial membrane. The dislocated end of the bone usually atrophies somewhat, and changes take place in its articular surface corresponding to the new conditions of friction; these changes are sometimes similar to those of arthritis deformans.

Symptoms and Diagnosis of Uncomplicated Traumatic Dislocations—The symptoms of traumatic dislocations are partly objective and partly subjective. The objective symptoms are: (1) A change in the contour of the joint; (2) a change in the relative positions of the articular ends of the bones; (3) a change in the axis of the limb; (4) a lengthening or shortening of the dislocated limb (Figs. 459, 460). The change in the contour of the joint is often evident to an experienced eye at the first glance. The patient should always be sufficiently undressed to render a comparison between the sound and damaged side possible: one can then note the normal configuration of the uninjured joint, the normal position of the bony prominences, the relationship of the

ls of the skin and soft parts on the healthy and the abnormal ›ressions and elevations on the diseased side resulting from the nged situation of the head of the dislocated bone. The most ›ortant symptom—viz., the abnormal position of the head of the ocated bone—can be recognised by palpation or by making move- ıts with the dislocated limb. The altered direction in which the er points is usually such that the long axis of the luxated bone s not strike the articular cavity of the other, but passes outside of in the case of the shoulder, for example, the long axis of the ıerus passes outside of the glenoid cavity (Figs. 459, 460). The ocated limb, in the majority of instances, is shortened, rarely ;thened, and assumes a position which is perfectly characteristic in ry dislocation.

The subjective symptoms are pain, and inability to perform normal ›ements with the injured limb. The disturbances of function usu- consist of a loss of active mo-, while passive movements are ›ible to some extent. The lat- are often very easily carried in a certain direction, while in ›rs they may be quite impos- e.

Fig. 459.—Subcoracoid dislocation of the left shoulder.

From what we have just said, ›llows that the diagnosis of dis- tions, especially soon after the dent, is usually not difficult. If swelling due to the effusion of ›d is very large, it can be re- ed in size by gentle massage, ›ibly under an anæsthetic. Dis- tions are most likely to be con- ›d with fractures of the articu- ends of the bones. The latter ; be suspected if the dislocation, rather, the deformity, is easily reduced by slight traction applied to injured limb, but returns again immediately when extension is dis- tinued. In dislocations, on the other hand, special manœuvres are essary to cause a disappearance of the deformity, and when reduc- ı has once taken place the change of contour does not again recur ntaneously. In fractures, abnormal mobility and crepitus are ally present, while in dislocations there is an abnormal fixation of limb, and certain movements are quite impossible. A kind of

crepitus is also sometimes met with in dislocations, but it is softer than bone crepitus, and is due to blood coagula and to the tearing of the ligaments of the capsule or of the tendons.

Complications of Dislocations.—The most important complications of dislocations are: (1) Extensive injury to the skin and subcutaneous soft parts over the joint; (2) fracture occurring simultaneously with the dislocation; (3) rupture of large vessels and nerves; (4) injury to internal organs.

Fig. 460.—Dislocation of the hip backwards (luxatio iliaca).

Division of the skin and subcutaneous soft parts with exposure of the head of the dislocated bone is not common; it is observed most often at the elbow, in the fingers, at the knee, and at the ankle. Such compound dislocations are always to be looked upon as serious injuries, especially when they are combined at the same time with fracture. The sooner a compound dislocation is subjected to antiseptic treatment the better will be the prospect of preventing infection and a serious suppurative arthritis (see § 123, Wounds of Joints).

The most common complication of a dislocation is a fracture occurring at the same time. The fracture may either involve the cortex, a portion of bone being torn off at the point of attachment of some ligament or tendon, or the fulcrum, or the dislocated bone itself, or the non-dislocated parallel bone, such as the ulna, which may be broken below the elbow in forward dislocations of the head of the radius. The fractures of least importance are those of the cortex and of bony prominences like the tuberosities of the humerus or the malleoli. Fractures of the rim of the acetabulum at the hip, and of the glenoid cavity at the shoulder, are, on the other hand, more serious, since they increase the difficulty of reduction or favour a recurrence of the dislocation. If a fracture occurs in a dislocated bone, the dislocation usually takes place first and then the fracture.

Rupture of large vessels or nerves is very rare, and is sometimes the result of unskilful reduction of an old dislocation. Stretching and crushing of the vessels and nerves are, however, more common. Crushing of the vessels occasionally gives rise to extensive thrombosis followed by gangrene, especially if the dislocation is not promptly reduced.

Of the injuries of nerves, those of the circumflex, with paralysis of the deltoid muscle, are the most frequent.

Of the injuries of internal organs, I should mention injury of the spinal cord in dislocation of the vertebræ, of the bladder, intestine, and pelvic organs in *luxatio femoris centralis*—i. e., dislocation of the femur inwards through the acetabulum, also compression of the trachea and œsophagus in dislocation of the sternal end of the clavicle, etc. Prochaska saw a case in which the head of the humerus penetrated the thorax between the second and third ribs.

Prognosis of Traumatic Dislocations.—As regards the prognosis, it is important for us to consider (1) whether we have to deal with a simple or a compound dislocation, (2) whether complications are present, and, if so, their nature, and (3) the region of the body and the particular joint where the dislocation has occurred. We usually expect perfect recovery to take place in the case of simple uncomplicated dislocations which have been successfully reduced. Should the dislocation not be reduced, a new joint or nearthrosis is formed, as we saw above, in the abnormal situation occupied by the articular end of the dislocated bone, particularly if the dislocation were one of the shoulder or hip. Occasionally a dislocation will recur from even a very slight amount of violence, and particularly if extensive movements are made with the joint at too early a period.

We sometimes meet with individuals who in this way suffer from very frequent recurrences of the same dislocation, especially that of the shoulder, jaw, or the hip, and there are people who have dislocated their shoulder or jaw more than fifty or one hundred times. These "habitual dislocations," as they are called, have many different causes, but they are usually due to a lax condition of the capsule and its accessory ligaments, which have become stretched and torn to such an extent that the cavity of the joint is enlarged, and a dislocation can take place without the occurrence of any fresh tear.

Treatment of Traumatic Dislocations.—The treatment of recent uncomplicated dislocations consists in bringing the displaced articular end of the bone back into its socket by special methods of reposition, and then immobilising the joint until the rent in the capsule has healed. The reposition was at one time carried out in a very forcible and rough way, and not infrequently with the aid of mechanical contrivances, pulleys, etc.; so that sometimes disastrous consequences—such as severe injuries to the skin, vessels, nerves, and muscles, or fractures—followed, and in some instances even entire extremities were torn away. At present we have in general anæsthesia an excellent means of rendering the reduction of dislocations easy and painless. An attempt should first be made to reduce a recent dislocation without an anæsthetic, and if this is found to be impossible chloroform should be administered, but with great caution, because a collapse resulting in death may easily take place, especially in habitual drinkers, who are

much excited by the accident. The sooner after the accident reduction is performed the more easily it is accomplished. The movements employed for reducing a dislocation must be carried out according to certain rules, which vary with the nature of the case, and in making them one should always take into consideration the shape of the joint and the nature and location of the rent in the capsule. *Impediments* to the reduction of recent dislocations are furnished by active contraction of the muscles, by the narrowness or unfavourable location of the rent in the capsule, by portions of capsule which still remain intact though stretched and abnormally situated, and by interposition of portions of the capsule, tendons, muscles, and fragments of bone. Active contraction of the muscles and the elastic tension of the soft parts are overcome by chloroform anæsthesia. It is evident that the movements made in accomplishing reduction must differ very greatly according to the nature of the case and the site of the dislocation; that sometimes rotation, sometimes flexion or extension, and sometimes abduction or adduction must be performed; and Krönlein is right in saying that it is not so much the etiology of a dislocation as it is its anatomy which determines our method of treatment. By means of the movements or manipulations aimed at reduction the head of the dislocated bone is brought opposite the rent in the capsule or the socket, and then, with a snapping sound or perceptible jolt, caused to enter the cavity of the joint. As a rule, it is well to combine with the above-mentioned manipulations a direct pressure upon the articular end of the dislocated bone. For the methods of reducing the various dislocations of the different joints I must refer the reader to the Regional Surgery. The restoration of the normal contour and functions of the joint will show at once that the reduction of the dislocation has been successful.

The after-treatment consists in keeping the replaced portions of the articulation at rest by means of light, immobilising dressings. In dislocations of the shoulder, for example, it will suffice if the arm is held firmly fixed by a mitella (see Fig. 181), which is secured in position by a few turns of a bandage around the arm and thorax. In dislocations of the hip the patient should be kept in bed, a spica coxæ (see Fig. 169) applied about the joint, and the limb immobilised by a cloth passed around the leg in the region of the knee. It is difficult to keep some joints reduced, as is the case with forward dislocations of the head of the radius and dislocations of the acromio-clavicular and sterno-clavicular articulations. In such instances an attempt must be made to hold the bone in place by dressings which exert pressure, by pads, or, when necessary, by the use of nails or bone sutures. After the lapse of some eight, ten, or fourteen days—depending upon the

nature of the case—passive motion of the dislocated joint should be begun in order to prevent subsequent stiffness. Extreme movements of the joint should, however, not be attempted during the next few weeks, because the healing of the lacerations in the capsule and ligaments may be interfered with, or the cicatrices of these structures may be so stretched that the dislocation easily recurs, or even becomes habitual.

The treatment of habitual dislocations, as a rule, is very difficult, particularly in marked cases. Long-continued rest of the joint in one position is usually unsuccessful, because the injured person has not the required patience. Very often nothing remains but to restrict the movements of the joint by means of a suitable bandage. In bad cases it may be well to expose the joint under antiseptic precautions, and either suture the rent in the capsule or resect the head of the bone. Genzmer successfully treated two cases of habitual dislocation—one of the shoulder and the other of the jaw—by the subcutaneous injection of pure tincture of iodine (0.5 to 0.75 cubic centimetres tinct. iodi. injected by a hypodermic syringe at intervals of three to four days, until six to eight injections have been made). Subcutaneous injections of absolute alcohol might also be tried.

In fresh dislocations which are irreducible an aseptic arthrotomy should be performed—i. e., the site of the dislocation should be exposed by an incision and the head of the bone then brought back into place, or resected if reduction is otherwise impossible. But recent simple dislocations seldom require operative interference, since reduction can generally be accomplished, especially if chloroform is used.

One should first try to reduce even old dislocations by the usual method, though they may have existed for weeks, months, or years; luxations of the shoulder and also of the hip have thus been successfully brought back into place two years after the accident. The possibility of reduction in these cases depends mainly upon the extent of the injuries which the soft parts have suffered, upon the greater or less degree of fixation of the dislocated articular end of the bone in its new position, and, finally, upon whether the joint cavity is much diminished in size or quite obliterated. After thoroughly anæsthetising the patient with chloroform, the same manipulations are employed for the reduction of old dislocations as for those which are recent, the articular end of the bone being first freed by rotatory movements. The manipulations aimed at reduction should be made with great care so as not to injure the bones or soft parts. The mechanical contrivances once so extensively used, such as pulleys, windlasses, etc., have become obsolete and have only a historic interest. Even though the reduction is suc-

cessfully accomplished a good result is not always assured, as the joint often remains stiff in spite of massage, electricity, and active and passive motion. If reduction is impossible, the dislocation should be exposed by an incision—i. e., arthrotomy should be performed and the head of the bone returned to its normal position, especially in those cases in which the limb has become useless owing to malposition, or in which the dislocated articular end of the bone causes pain and paralysis by pressing upon the nerves. In such instances resection of the articular end of the bone will often be necessary as a preliminary step in performing reduction. At the hip the position of the limb is sometimes best corrected by osteoclasis or subtrochanteric osteotomy. In other cases of old irreducible dislocations one may try to make as good a nearthrosis as possible by means of massage, passive motion, electricity, and warm baths.

Dislocations in which the joint is opened are treated by the same rules that apply to wounds of joints (see page 723). Under these circumstances, also, reduction should be performed as promptly as possible, taking every antiseptic precaution and providing for drainage of the joint. According to Drewitz, reduction without resection of the head of the bone gave, even in preantiseptic times, movable joints in forty per cent. of the cases. If difficulties are met with in performing reduction the knife should be made use of, and when reduction has been accomplished the joint should be carefully drained and immobilised. If the soft parts have been very much injured permanent irrigation should be employed. Resection of the head of the dislocated bone is indicated in cases complicated by comminuted fractures, extensive injury to the soft parts, suppuration within the joint, or where reduction is impossible by other means. If sepsis has already made its appearance prompt amputation or disarticulation may be necessary.

If both dislocation and fracture occur together, it should be our first aim to reduce the dislocation when this is possible, using, for example, direct pressure upon the articular fragment in the case of dislocation and fracture of the humerus at the shoulder joint. In other instances reduction of the dislocation may be impossible, and the fracture must first be allowed to heal before the dislocation is attended to. In suitable cases operative measures must be undertaken—i. e., the seat of injury should be exposed, and whatever measures the condition calls for adopted. The prognosis of all dislocations which are complicated by fracture should be looked upon as doubtful as regards restoration of the normal mobility of the joint.

The other complications, such as injuries to vessels and nerves, are to be treated in the usual way (see § 88).

Dislocation of the semilunar cartilages of the knee rarely occurs independently of other changes in the joint. Habitual dislocation of these cartilages has been observed, the most common variety being a displacement of the inner cartilage forwards, due to forced flexion of the knee-joint combined with outward rotation of the foot, or, rather, leg. The displaced cartilage can be felt on the anterior border of the joint, the knee is somewhat flexed, and complete extension is impossible.

For a description of dislocations of tendons and nerves see pages 525, 526.

II. **Pathological or Spontaneous Dislocations** are observed in the course of diseases of joints either as a result of an abnormal stretching or lax condition of the capsule and ligaments, or of changes in the articular ends of the bone such as those caused by arthritis deformans or caries. Under such circumstances either an incomplete or a complete dislocation takes place, coming on gradually and brought about by the weight of the limb, or suddenly from some slight traumatism, muscular action, etc.

We distinguish: 1. *Distention Dislocations*, due to a stretching or lax condition of the capsule and ligaments of the joint caused by a serous, sero-fibrinous, or more rarely suppurative effusion. Complete and incomplete dislocations of this kind are especially common in the course of metastatic inflammations of joints with large collections of fluid, such as occur in typhoid fever, small-pox, measles, scarlet fever, diphtheria, puerperal fever, and pyæmia. The capsule and ligaments of a joint—the shoulder, for example—may also become stretched in cases of muscular atrophy and paralysis. Under these conditions the muscles are not capable of supporting the extremity, and thus allow displacements of the joint surfaces to take place either gradually or suddenly. The voluntary dislocations mentioned on page 741 are likewise looked upon by some authors as distention dislocations.

Quite recently Verneuil has called attention to dislocations which occur during acute articular rheumatism and run a course exactly like that of traumatic dislocations. In all cases the luxations took place suddenly and spontaneously, and could be reduced very easily under an anæsthetic. In other cases when the dislocation could not be reduced, resection—of the hip, for example—had to be performed. Verneuil thinks that these dislocations are caused by muscular action and a lax condition of the ligaments.

2. *Destruction Dislocations.*—The most common form of pathological dislocation is due to a carious destruction of the joint surfaces combined with corresponding changes in the capsule and ligaments. In this category belong the so-called "wandering of the acetabulum" in coxitis (page 701, Fig. 441) and the spondylolisthesis—i. e., the slipping down of the last lumbar vertebra into the pelvis in cases of

tubercular destruction of the corresponding intervertebral ligaments (see § 114).

3. *Deformity Dislocations*, which are the result of changes in the shape of the bony parts of the joint due to an atrophy of bone without suppuration and without the production of granulations. They most commonly occur in connection with arthritis deformans (see page 686, Fig. 447).

Fig. 461.—Congenital dislocation of the left hip in a six-months-old girl: *a*, remains of the capsule which has been dissected away; *b*, undeveloped acetabulum.

For the course, diagnosis, and treatment of pathological dislocations see § 113, § 114, § 119 (Inflammations and Deformities of Joints), and the above description of traumatic dislocations.

III. **Congenital Dislocations.** — Congenital dislocations are mainly the result of anomalous or arrested fœtal development. They are most common at the hip (Fig. 461), being very rarely found in the rest of the joints, and are occasionally combined with other anomalies of development, such as club-foot, spina bifida, and exstrophy of the bladder. These congenital dislocations, which take place *in utero*, should not be confused with the traumatic ones which take place during delivery and are due to extraction of the child. This latter form of dislocation is, however, extremely rare, fractures, especially at the epiphysis, on account of the latter's slight power of resistance, being much more common. But it is probable that in some cases extraction of the fœtus causes a stretching of the capsule, thus furnishing a predisposition to dislocation which subsequently becomes more marked as the joint is used in walking.

Investigations relating to the Pathology and Etiology of Congenital Dislocations.—These investigations have to do almost exclusively with congenital dislocations of the hip. I have had opportunities of examining dislocations of this kind in female children at the autopsy (Fig. 461). I have usually found the acetabulum abnormally flat and the head of the bone lying at its upper and posterior border. The neck of the femur usually forms an obtuse angle with the shaft. The capsule of the joint is generally normally formed. In one case I found in a female child six months of age that the ligamentum teres was so much thickened and lengthened that the head of the femur, which was situated near the anterior superior spine, did

not have sufficient room in the shallow acetabulum. The pelvis was, moreover, asymmetrical.

Congenital dislocation of the hip is usually one-sided; out of 198 cases, Hoffa found that 134 were one-sided. At the outset the head of the femur is in the vicinity of the upper and posterior edge of the acetabulum, and is later pushed upward and backwards on to the ilium. Lordosis of the vertebral column is present, especially in bilateral dislocations, and the patients have a very characteristic gait, like that of a duck.

The main cause of congenital dislocation of the hip is probably to be found in an imperfect development of the acetabulum or the cotyloid ligament, and its occurrence is favoured by extreme flexion and adduction of the thighs of the fœtus (Fig. 462, Dupuytren, Roser). A very small uterus, which exerts abnormal pressure upon the fœtus, thus causing the latter to assume a cramped position, may possibly have a deleterious influence upon the development of the hip-joint. The obtuse angle which the neck of the femur makes with the shaft (Fig. 461) should also be noted, as this is probably not always a secondary condition, but one which may sometimes develop primarily from the above-mentioned cramped position of the fœtus brought about by a uterus which is deficient in size. Owing to the obtuse angle which the neck of the femur forms with the shaft (Fig. 461), the head, as it were, grows past the acetabulum instead of into it. Other cases of congenital dislocation are probably the result of an abnormally long and thick ligamentum teres, which, as in the case I examined, does not give the head sufficient room in the acetabulum. In older children the ligamentum teres is usually absent. In consequence of the abnormal position of the head of the bone the muscles are mostly shortened, and the direction of their action is altered. Another important fact, from an etiological point of view, is that congenital dislocations of the hip are much more common in females than in males, 87.6 per cent. of all cases occurring in the former sex.

Fig. 462.—The manner in which a congenital dislocation of the hip is produced: the leg of the fœtus is forced to assume an abnormally adducted position by a uterus which is too small (W. Roser).

From careful examinations which I have made of the fœtal pelvis, I believe that this latter fact can be explained by the comparatively vertical position of the ilium in females, which, in conjunction with the abnormal angle formed by the neck of the femur with the shaft, readily allows the head to leave the shallow acetabulum and glide up on to the ilium.

It follows from what has been said that the congenital dislocations of the hip are undoubtedly to be ascribed to anomalies in the development of the fœtus due to various causes.

The rare cases of congenital dislocations of other joints of the body are probably also due to anomalies of fœtal development. Congenital subcoracoid, subacromial, and infraspinous dislocations of the shoulder have been reported, as well as congenital dislocations of the elbow, wrist, knee, and ankle. At the elbow, congenital dislocation of the

head of the radius—backwards, outwards, forwards, or inwards—is the most common.

The symptoms, diagnosis, and treatment of congenital dislocations of the different joints are taken up at length in the Regional Surgery, and I will only briefly state here that the prognosis is usually unfavourable. Still, the treatment of congenital dislocations of the hip has recently made marked progress, owing to the labours of Hoffa, Lorenz, and Mikulicz. (For further particulars see Regional Surgery.) With the aid of the X-rays it is possible to determine the results of the different methods of treatment.

FIG. 463.—Double congenital dislocation of the hip.

§ 123. **Wounds of Joints.**—Wounds of Joints consist of punctured, incised, and contused wounds, and wounds which are complicated with fracture, including gunshot wounds (see § 124). Any wound which opens a joint—a so-called penetrating wound—even though extremely small, should be looked upon as a very serious injury, since it may more or less completely destroy the function of the joint, and even imperil the life of the patient. The escape of synovial fluid is a symptom which indicates beyond a doubt that the joint has been opened. The prognosis of penetrating wounds of joints is, however, much more favourable than it was before the introduction of the antiseptic method of treating wounds, and we now have no fear of opening a joint aseptically with the knife or trocar. But the conditions are entirely different in the case of accidental wounds made with an unsterilised instrument, or of gunshot wounds into which dirty pieces of clothing have perhaps entered. Under such circumstances germs of infection can readily make their way into the joint, and with great rapidity cause violent inflammation.

The course of a penetrating wound of a joint depends very largely upon whether or not germs of infection have gained access to the joint at the time of the accident, or afterwards.

We shall first discuss the cases in which everything is most favourable—i. e., in which no infection of the wound, a punctured one, for example, has taken place. The course of such a wound will then be as follows: The synovia makes its appearance at the time of the accident, but soon ceases to flow out, and the wound becomes agglutinated and heals up without causing any inflammation or disturbance of function in the joint. In other cases a mild inflammation occurs, taking the form of a serous or sero-fibrinous synovitis.

The course of an infected wound of a joint is quite different. Infection may take place at the time of the accident or later, and is then due to improper treatment or dirty probes, or to the fact that the patient pays no attention to the wound, and walks about, thus, by his movement of the parts, permitting air and infectious germs to have free access to the joint. In some cases the wound has already united, and then on the third to the fifth day manifestations of inflammation suddenly make their appearance, and rapidly increase in severity. The joint is swollen, tense, and very painful, the skin is red and feels hot, and there is high fever. If the agglutinated borders of the wound are separated by a probe, or if the sutures are removed, pus immediately makes its appearance. Other cases, especially those in which there is a large effusion of blood, run a more acute course, and the local and general symptoms of suppuration in the joint come on within twenty-four hours after the injury. These are the most unfavourable ones, and unless the infected contents are promptly removed by freely opening up the joint, followed by drainage and antiseptic irrigation, or, if necessary, by resection, acute gangrene of the joint may rapidly follow, with, perhaps, general sepsis.

In another group of cases the course is more subacute, and though the exudate within the joint is very large it is not noticeably suppurative in character, but looks like cloudy synovia mixed with flakes containing pus-cells (see § 113).

The final outcome of an infected wound of a joint varies, though if it receives antiseptic treatment early enough recovery is assured. In some cases, after a longer or shorter time, the suppurative inflammation gradually gets well spontaneously without any particular antiseptic treatment, but in others which are not properly attended to the suppuration becomes progressive, breaks through the capsule of the joint, and gives rise to suppuration in the neighbourhood, while the inflammation in the joint itself apparently diminishes in intensity. Such suppurative processes not infrequently run a very tedious course, gradually going on to pyæmia, to which or to extreme exhaustion the patient succumbs. The worst cases are those in which death occurs

from acute septicæmia within a few days. These septic or gangrenous inflammations of joints may be caused by a very slight injury, such as puncture of the joint with a sewing needle, and they may run such a rapid course that even on the fourth or fifth day death from septicæmia cannot be prevented even by amputation or disarticulation. We have already described the course and outcome of the different varieties of acute inflammations of joints in the chapters devoted to Joint Inflammations.

The Repair of Wounds in Cartilage.—Gies has made experiments on young dogs with reference to the repair of wounds made in cartilage and has come to the conclusion that clean aseptic wounds in this tissue never heal, but remain permanently unchanged, while wounds which are made in the presence of micro-organisms heal up so completely as not to leave any or scarcely any traces behind them.

The escape of synovial fluid in all recent cases which come under observation immediately after the reception of the injury has, as we remarked before, a very important bearing upon the diagnosis of penetrating wounds of a joint. In some instances in which the joint is laid wide open the exposed articular cartilages may be recognised at the first glance. But not infrequently the puncture or other wound is already closed, so that it is doubtful whether the joint has been opened or not, and under these circumstances we must quietly wait for further developments. A warning should be given here against probing wounds too freely in the neighbourhood of a joint.

Treatment of Wounds of Joints.—Every wound of a joint, even the most trivial, should be treated with the greatest care. We shall not discuss the treatment of gunshot wounds of joints, as they will be taken up later in § 124.

Absolutely fresh cases without much effusion into the joint, and without apparent infection, are treated by disinfection of the wound and its neighbourhood. I do not, as a rule, suture such wounds, but merely dust them with iodoform, cover them with iodoform or bichloride gauze which has been moistened in a 1-to-1,000 solution of bichloride of mercury, and over this place sterilised cotton. Large wounds should be packed with iodoform or sterilised gauze. The antiseptic occlusive dressing should be as large as possible, and the joint must be carefully immobilised by splints. The time for changing the dressings depends upon the subsequent course of the injury, and very often aseptic healing takes place without changing the dressing at all. But should fever make its appearance and the patient complain of pain, the dressing must be changed immediately. If, upon taking off the dressing, it is evident that the joint has become infected and that an acute suppu-

rative inflammation has developed, thorough disinfection and drainage of the joint must be begun at once. The joint should be freely opened, all pockets within it disinfected with a 1-to-1,000 bichloride solution, and any blood-coagula that may be present carefully removed. Short and thick drainage tubes—preferably of glass—must be inserted in those places where they can most effectually help to carry off the discharges. In suitable cases the wound is packed with iodoform gauze or sterilised mull, and it is also of the greatest importance to secure immobilisation of the joint. The dressings must be changed often, depending upon the height of the temperature. Not infrequently one has the pleasure of seeing that this treatment is followed by excellent results, that the inflammation of the joint is averted, and that, even in cases where one could hardly have expected it, perfect mobility of the joint is regained despite the fact that suppurative arthritis has occurred.

If, in spite of disinfection and drainage of the joint, severe constitutional symptoms make their appearance, or if the suppuration that is present is very extensive, so that drainage of the joint presents great difficulties, resection is then indicated; or, if general systemic infection threatens, the focus of infection must be removed by amputation or disarticulation.

If the patient comes under treatment after suppuration has already begun, antiseptic incision and drainage, or packing of the joint with or without resection, or even amputation are indicated, depending upon the amount of suppuration and the length of time the disease has lasted. In opening up infected cases of this kind one should not be afraid of making too many incisions into the different parts of the joint. Continuous antiseptic irrigation will often be found a most excellent aid in the subsequent treatment (see page 181). Any complications that may be encountered—fractures, for instance—are to be treated in the usual way. (See page 622, Treatment of Compound Fractures.)

Appendix.

Gunshot wounds. Military practice.

§ 124. **Gunshot Injuries.**—In connection with wounds of joints, we shall give a short description of the gunshot wounds which have already been referred to several times in speaking of injuries to the different tissues. We must, of course, confine ourselves here merely to a brief sketch, and whoever cares to become better acquainted with this extremely interesting subject should read the excellent works of Stromeyer, Pirogoff, Langenbeck, Billroth, Esmarch, etc. The literature of gunshot wounds and military surgery is very extensive. Of the

older books, I should speak especially of the memoirs of Larrey, the famous army surgeon of Napoleon I, and, among English works, of The Principles of Military Surgery, by John Hennen.

Gunshot wounds are essentially contused and lacerated wounds, and are most commonly caused by hand firearms. The projectiles of the latter (shot-guns, revolvers, pistols) are generally cylindrical or shaped like an acorn, and are usually made of lead. The bullets used in modern weapons—i. e., those of small calibre (eight millimetres), at present employed by the European armies—are long and cylindrical, and consist of a lead core encased in steel. Owing to this steel covering the bullets are very resistant and retain their shape when they strike a bone or pass through the body. The penetrating power of these bullets is, as we shall see, very extraordinary. The lead bullets become so soft from friction as they pass through the barrel of the gun and the air that they change their shape very materially and break up into single pieces, so that an explosive effect results. When they strike bone, for example, they become flattened out, split, shattered, or broken up into irregular, pointed fragments of lead. In the case of shots fired from a short distance the bullet is heated to a very high temperature, and, as we shall see, it is under these circumstances that its explosive action is most likely to take place.

Bullets cause the following injuries: 1. The mildest form of gunshot injury is contusion of the soft parts, with extravasation but without a wound. These contusions of the skin or soft parts are usually made by spent balls coming from a great distance. In rare cases subcutaneous fractures are also produced in this manner. Occasionally the contused, undivided skin is pressed inwards like a pouch, thus causing, when the bullet strikes upon the abdomen, contusion and laceration of internal organs, of which the liver may be one. Moreover, bullets which have a great velocity can be so checked by striking a watch, purse, pocketbook, pieces of leather on the uniform, etc., that only a contusion without any wound results. Bullets of small calibre with a covering of nickel or steel cannot be stopped in this way, as they have an extraordinary penetrating power.

2. *Furrowed wounds* are caused by bullets which graze the surface of the body and carry with them a portion of the skin, so that a more or less deep furrow is formed.

3. The most common gunshot injuries are *tubular wounds*—i. e., the ball passes through the skin and enters the soft parts, where it either remains lodged (so-called blind shot canal) or comes out again at another part of the body ("seton shot"), thus making an opening where it entered and one where it emerged. The differentiation of

the points of entrance and exit is of importance notably from a medico-legal point of view. The point of entrance is usually more or less indented, depending upon the size of the bullet, and is coloured bluish-black, while the exit opening is generally smaller and looks more like a tear. These points of difference do not, however, always hold good, as the opening of exit is sometimes larger than that of entrance, particularly when a bone is splintered or when the ball changes its shape or becomes broken into pieces. Occasionally several points of exit are found, especially if the bullet has been fired at short range, as this produces an effect like an explosion, shattering the bone into separate splinters, which perforate the skin. The burning of the integument is often very extensive when the revolver or pistol has been discharged close to the body, as in attempts at suicide, and then, owing to the healing into the tissues of small particles of powder, the skin often remains of a greyish-black colour for the rest of life. The same is true of small shot, which, when fired from near at hand, can also cause very extensive destruction of the region where they strike, and particularly severe shock, giving rise to such marked symptoms of collapse that the patient may die soon after the injury. Quite recently I saw a bad case of collapse occasioned in this way, in a hunter who was struck by fifty-two pieces of shot; but in spite of having sustained wounds of his lungs, pericardium, and intestine, the patient recovered.

The direction of the track of the bullet is sometimes very peculiar, and instances are recorded where it encircled the thorax close to the ribs without injuring the pleura or the lungs. The entrance into a gunshot wound of unclean foreign bodies, such as bits of cloth, leather, or linen from the clothing, has a very important bearing upon the subsequent course of the injury, as substances like these are extremely apt to give rise to infection provided the micro-organisms they contain are pathogenic and remain capable of development.

The modern artillery projectiles, such as grenades, cannon balls, shells, etc., often give rise to severe injuries similar to those caused by machinery in times of peace; entire extremities may be torn from the body, and death can be instantaneous. But slight wounds, such as contusions and superficial lacerated wounds, are likewise frequently caused by the same missiles.

The gunshot injuries of bone are, as a rule, (1) *compound comminuted fractures.* The number of fragments is sometimes very large, and, in addition, there are many fissures, as illustrated in Figs. 390, 394–396, 464. The splinters of bone are often driven into the soft parts or even through the skin, forming, as we stated before, several exit openings. Not infrequently the bone is crushed to a pulp.

There are also found in bone (2) *tubular or circular gunshot wounds*, with or without splinters or fissures. The latter, in Fig. 464, unite the points *a* and *b* of entrance and exit of the missile. (3) *Subcutaneous fractures* caused by a spent ball have already been spoken of. The mildest form of injury to bone is (4) *contusion*, with an extravasation of blood into the periosteum and bruising of the bone substance. Sometimes hollows or depressions, together with fissures, are formed in the bone against which the bullet is flattened out, or the latter is found impacted, being in some cases split in two and seated astride of the broken edge of a fragment.

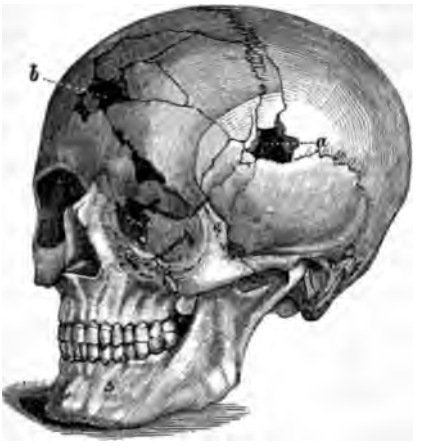

FIG. 464.—Gunshot injury of the skull (in a Russian soldier killed in the battle of Plevna), with numerous fissures which run from one opening (*a*) to the other (*b*) (Bergmann).

In rare instances a gunshot fracture takes place not directly at the point where the bullet strikes the bone, but at some distance from it, and either exists by itself or is combined with a fracture at the point where the bullet struck (Lacronique). These indirect gunshot fractures may result from a bend, a twist, or concussion of the bone in question, and occasionally by a union of several of the fissures which radiate from the point where the bone has been struck by the bullet.

Gunshot injuries of joints are in the main complicated wounds with or without injury of bone. The most severe gunshot injuries of the joints are those with splintering of the articular ends of the bones.

The Effects produced by Modern Projectiles.—Bush, Kocher, and others have made some interesting experiments pertaining to the action of projectiles constructed of lead and the kind of damage they cause in the tissues; and Reger has recently studied the action of such projectiles upon bone, and has come to some practically important conclusions. In the case of injuries made by soft lead within a range of four hundred metres, an effect is produced which is like an explosion; the wound is funnel-shaped, and the bone is crushed to fragments, which penetrate the soft parts posteriorly, making the opening where the projectile emerges ten to twenty times as large as the opening where it entered. In the case of gunshot wounds made at a range of five hundred to one thousand metres, a clean-cut, penetrating wound is made, with or without radiating fissures. If the projectile traverses the longitudinal axis of the bone, extensive splintering of the latter may be pro-

duced. In the case of wounds made at a range of one thousand to fifteen hundred metres, comminuted fractures with considerable shattering of bone not infrequently occur in spite of the diminished momentum of the projectile. At longer ranges there is a slight splintering or contusion of the bone, in which the bullet will often be found impacted.

The Action of Projectiles of Small Calibre (Eight Millimetres in Diameter) with a Steel Coating.—Chauvel, Bovet, Kocher, and others have made experiments on the cadaver and living animals with the small-calibre (eight millimetres in diameter) projectiles covered with nickel or steel, which are in general use. All the experiments show that these projectiles have a great penetrating power on account of their tremendous velocity, and this has been still further increased by the use of smokeless powder. The projectiles which are coated with steel retain their shape, while those made of lead become deformed on account of their comparative softness. At short ranges, however, the action of the projectiles which are covered with steel and those made entirely of lead is very much the same, except that the penetrating power of the former is greater; for example, three cadavers placed fifty centimetres behind one another were shot through at a range of six hundred metres (Demosthen). According to Bruns, these steel-coated projectiles can pass through iron plates twelve millimetres in thickness, or pine wood one hundred and ten centimetres thick, at a range of twelve metres. At a distance of fifty metres the bullet penetrates tree-trunks sixty centimetres in diameter. It only rarely happens that a steel-coated bullet remains in the body. Even at ranges of twelve hundred metres up to two thousand metres it passes completely through the body. The steel-coated bullet, in case it does not lose its covering by first striking some hard object, such as a rock, keeps its form and makes smooth wounds in the soft parts with small entrance and exit openings. It is more resistant than the nickel bullet. At a range of four hundred metres Bruns found that it produced an effect like an explosion upon the skull only, the long hollow bones not suffering such extensive injury; at a range of eight hundred metres perforating wounds occurred; and even at a range of twelve hundred metres two or three parts of a body placed one behind the other were completely shot through. The projectiles rarely remain in the body, as Hobart and Chauvel have noted by experiments made at ranges as long as fifteen hundred to two thousand metres. In general, the modern projectiles of small calibre which are covered with steel are more humane than those made entirely of lead, and, except at the ranges where explosion of the projectile takes place, the wounds they make have a more favourable prognosis, since the bullets do not become shattered, but make a smooth puncture with small openings. The firearm of small calibre is the most powerful weapon of modern times, on account of its great velocity, long range, and tremendous penetrating power.

The observations made upon the living with projectiles of eight millimetres diameter correspond very closely with the above experiments. Up to certain ranges (twelve hundred to two thousand metres) projectiles which strike the body directly pass entirely through it, forming small openings at their points of entrance and exit; but if, before entering the body, they rebound from a rock or piece of iron, they rarely do this. In these rebounding

shots the steel-covered bullets lose their shape and become bent, the steel covering bursts, etc., and accordingly the wounds they make are torn and mangled, and the openings they form on entering and coming out are much larger. Certain varieties of bullets have an especially destructive action upon the tissues. Of these the bullets with a partial nickel covering (lead-tip bullets), the so-called dum-dum bullets, and the hollow-tip bullets are the best known. The reports of the English surgeons Davies and Hamilton, and the experiments of Bruns and Wendell, show that the lead-tip bullets, particularly when fired at close range (two hundred to five hundred metres) cause very severe wounds—i. e., much more laceration of the soft parts, and more comminution of the bone than the usual completely coated bullets. This explosive action of the lead-tip bullets is explained by the fact that the exposed lead tip changes its form in passing through the body, breaks the steel coating into small and minute pieces, and the lead also breaks into small fragments, particularly when the bullet strikes bone. The hollow-tip bullets have a similar action. At short range they cause a great deal of destruction, particularly in the viscera that are filled with fluid. The use of both kinds of bullets in war should be strongly protested against.

The Course of Gunshot Wounds.—The course of gunshot wounds may be inferred from what we have already said of injuries to the soft parts, bones, and joints, and the reader is referred to the paragraphs which treat of these subjects. The pain is usually trifling, as the wound is made so quickly, and often a person does not know that he has been hurt until he notices the blood. The hæmorrhage may be very slight even when large, deep-seated arteries have been injured, and it ceases spontaneously by the formation of a thrombus and by the pressure of the surrounding parts. In other cases the wounded person dies in a few minutes, or even sooner, if a large artery such as the femoral or the carotid has been divided.

The subsequent course of a gunshot wound depends upon whether, at the time of the injury or afterwards, infectious substances (bacteria) have gained access to the wound by means of dirt of various kinds, pieces of clothing, or unclean fingers, instruments, etc. The temperature of the projectile at the moment when it struck the body is another matter which has an important bearing upon the course of the wound, as the micro-organisms are often killed by the heat of the ball, especially if it is of small calibre and has a nickel or steel covering. Hence infection of gunshot wounds on the battle-field is almost always due to the fact that immediately after the injury, or not until later, micro-organisms gain access with the dirt, or from insufficiently disinfected fingers and instruments. This infection may give rise to the various diseases of wounds, such as progressive inflammation and suppuration, sepsis, and pyæmia. Tetanus is also not infrequently observed, especially if earthy materials have come in contact with the wound. If,

however, infection does not take place, even very extensive injuries to bones and joints heal readily.

Gunshot wounds inflicted at a short range, in which both soft parts and bone are badly mangled, have the worst prognosis, and in many cases, especially in wounds involving the trunk, head, or abdomen, death is instantaneous. If a patient with such a gunshot wound of an extremity remains alive, a conservative plan of treatment is usually hopeless, and amputation or disarticulation is indicated. It has already been remarked that the modern steel-coated projectile of small calibre, in spite of its great penetrating power—leaving out of consideration the range within which it explodes—makes a cleaner wound than the old-fashioned soft lead projectile, which mangles and lacerates both bone and soft parts. The steel-coated bullet retains its form in case it does not first strike a rock, etc., and causes smooth non-contused and non-lacerated wounds. These bullets often heal up in the tissues without reaction, and not infrequently change their location, coming to the surface at some other part of the body. Küster observed chronic lead-poisoning result from a bullet that had remained in the tibia for seventeen years.

Treatment of Gunshot Wounds.—Gunshot wounds are treated, in general, according to the same principles which we have already given for the treatment of injuries to the soft parts, bones, and joints. Nevertheless, I shall discuss the treatment of gunshot wounds somewhat more at length, with particular reference to their treatment in times of war. For the special treatment of penetrating wounds of the head, thorax, and abdomen the reader is referred to the Regional Surgery.

We think with a shudder of that period of the middle ages when gunshot wounds were wrongly looked upon as poisoned wounds, and were therefore burned out with boiling oil in order to destroy the venom of the powder. Ambroise Paré and Maggi successfully combated this method of treatment in 1551 and 1552. The story is told that when the army of King Francis of France stormed the little castle of Villane, near Susa, Ambroise Paré did not have sufficient hot oil at hand to burn out all the gunshot injuries in accordance with the treatment then in vogue. On the next day all those wounds which had not been burned out with oil were free from pain and inflammatory swelling, while those which had been thus treated were very painful and much swollen. After this experience Paré always denounced this cruel method.

Every gunshot injury should, of course, be treated according to antiseptic principles, although this is quite a different thing in times of

peace from what it is in war, when, on account of the great numbers of the wounded, it is not possible to attend to every case as carefully as we are ordinarily accustomed to. It is hence very natural that the expectant treatment of gunshot injuries has been recommended again, particularly for the first few days after the battle. This does not apply to the very severe injuries which require immediate operative interference (see page 764). The expectant treatment applies chiefly to gunshot injuries with bullets of small calibre. Generally speaking, the ordinary rules of aseptic surgery are also applicable to military practice.

It is especially important to check the hæmorrhage and remove all foreign bodies that may have got into the wound, such as bullets, unclean pieces of clothing, etc. But it is a bad plan to hunt for a bullet too industriously or too long, as it subsequently heals up in the tissues, just like other foreign bodies. Dementjew and Bergmann saw in the Russo-Turkish War eighteen cases in which the ball healed up within the knee-joint. Subsequently the projectiles sometimes leave their original positions and wander about, like needles or other similar bodies. Bergmann and Reyher made very successful use of the expectant treatment during the Russo-Turkish War, even in cases of injuries involving joints. They confined themselves to a disinfection of the wound and its neighbourhood, and then immobilised the extremity in plaster of Paris with or without an antiseptic occlusive dressing. The parts often united *per primam intentionem*, the bullet becoming enclosed, while in other instances suppuration took place, and yet the bullet remained where it was. The expectant plan of treatment may be accompanied by dangers when there are pieces of clothing in the wound; but these form the minority of cases, and there are usually no such sources of infection present. If one decides to adopt operative measures and enlarge the wound, in order to check hæmorrhage, for example, or on account of inflammation or suppuration, one must, of course, proceed according to general antiseptic principles. In civil practice one will not make so much use of the expectant form of treatment for gunshot fractures, but will follow the ordinary rules which govern the management of compound fractures. In cases of wounds with extensive mangling of the soft parts and bone, conservative treatment is usually hopeless, and amputation is in general indicated.

It is especially important that the wound should not be examined with fingers or instruments which have not been disinfected, except, perhaps, in the face of serious hæmorrhage which threatens the patient's life. Many a wounded person has lost his life through examination of his injury with a finger or a probe which had not been

properly disinfected. Reyher is right in discriminating between "fingered" wounds—i. e., those which have already been examined by a physician—and "unfingered" wounds—i. e., those which come directly under the surgeon's care. Out of eight patients with "fingered" injuries of the knee, six died and one was in great peril, while of seven "unfingered" injuries of the knee six recovered.

The primary antiseptic treatment consists either of antiseptic occlusion of the wound in the skin or antiseptic drainage. In the former—i. e., in healing under a scab—all exploration of the wound with a probe or the finger should as far as possible be avoided. If, however, an exploration of the wound is absolutely necessary on account of dangerous hæmorrhage, infection of the wound, etc., drainage must at the same time be provided for, and any operative measures which may be necessary, such as removal of splinters of bone, resection, or amputation, must be undertaken at once. An excellent method of drainage in case of large gunshot wounds is to pack the latter with iodoform gauze or sterilised mull. Every gunshot wound is treated by the open method—i. e., is not sutured. The best antiseptic for military practice is bichloride of mercury. The dressing should be as simple as possible. In some countries the soldier is supplied with the material for the first dressing in the form of a small bundle which can be sewed into his coat or carried in the breast pocket or knapsack. I think this plan of letting each soldier apply the first dressing with the materials which he carries with him is a bad one, since these dressings are anything but antiseptic—in fact, they are usually full of dirt. It is much better that there should be a large number of surgeons and well-trained assistants upon the field furnished with sufficient antiseptic dressing materials, and that the dressings which the soldiers carry with them should only be used in an emergency. These consist of two pieces of compress impregnated with bichloride, one bandage, a safety pin, and a three-cornered piece of cloth, all of which are wrapped up in some rubber material. In order that antisepsis may be properly observed in time of war all persons entrusted with the care of the wounded should be previously instructed in the general principles of antiseptic treatment and in the technique of applying simple antiseptic dressings. The voluntary assistance of persons in the higher walks of life, especially students, is very desirable in this connection.

The sterilisation of dressings can be carried out in times of war according to the same principles as in times of peace, and hence it is not a good plan to make a collection beforehand of dressing materials which have been impregnated with antiseptics, as they will be subsequently found to contain bacteria in spite of the best of packing. The

most suitable kind of dressings are those which can be transported in the smallest possible bulk, such as mull, hemp, and cotton. The common salt-bichloride tablets which Angerer has recently recommended for military practice are very useful, and greatly facilitate the preparation of permanent bichloride solutions. Instead of sponges, aseptic gauze pads are to be recommended.

On the battle-field the wounded are first carried to a covered place marked by the red cross flag, which is the first dressing place. The wounded are dressed here provisionally, and in some cases permanent dressings are put on. From here they are moved to the nearest field hospital. The dressings at the first dressing station are applied according to the rules of antisepsis; not only sterile dressings are used, but also antiseptic powders, such as iodoform, dermatol, etc. The duties at the first dressing place consist in the prevention of wound infection, in conservative treatment of gunshot injuries—e. g., of the extremities—and in immediate interference in the case of dangerous injuries (arrest of hæmorrhage, ligation of large vessels, amputation, tracheotomy). At the first place only the most necessary life-saving operations should be performed. The most seriously wounded, especially those who cannot get to the first dressing place, should be attended to first. It has been said that in future battles the disproportion between the number of the injured and that of the surgeons will be even more evident than it has been in the past, as the rapid-firing guns now used, on account of the greater accuracy of their aim, will probably increase the numbers of the wounded, while the number of surgeons will remain about the same. Billroth likewise expressed the fear that the number of wounded in coming battles will be so great that there will not be sufficient help at hand to render them the necessary assistance while the battle is going on. In my opinion, however, there is no ground for these fears. In spite of the increasing perfection of the guns used in the modern battles the latter are less bloody, for the reason that fighting at close range has become rarer, and the protection of the ground is made more use of than formerly. The bloodiest battle of the nineteenth century is said to have been the battle of Leipsic, where there were 90,000 killed and wounded; the next bloodiest was the battle of Aspern, in which there was a total loss of 66,000; and then Borodino, with 62,000. Aspern had the highest percentage of killed and wounded (38 per cent.); then come Borodino, with 25 per cent.; Eylau and Waterloo, with 24 per cent.; Leipsic and Inkerman, with 21 per cent. On the other hand, the relative loss in dead and wounded at Königgrätz was 7.5 per cent., at Gravelotte 16 per cent., at Sedan 12 per cent., at Wörth 13.5, at Mars la Tour 16 per cent., and at Plevna 14

per cent. These figures give the percentage for both armies. If we examine the losses of the separate armies—e. g., on the German or French side—we find here also that the greatest losses in the large battles of modern times were smaller than they used to be, and have never reached a fourth of the whole strength of the army. The Germans lost at Mars la Tour 22 per cent., the French at Wörth 16 per cent., and at Sedan 19 per cent. The Austrians lost at Königgrätz 11 per cent., and the Russians at Plevna 17 per cent.

But quite apart from the fact that battles in modern times are less bloody than they used to be, the German army organisation has provided for a sufficient number in the hospital corps to render first aid to the wounded. Haase states that the organisation for the care of the wounded which the German army possesses will amount in future wars to forty-five thousand well-trained men (hospital orderlies, carriers of the wounded, etc.). Thus we can see that a liberal provision has been made. At the field hospitals, which are usually churches, schoolhouses, or other large buildings, or tents and barracks, the wounded who are brought in with temporary dressings on are examined with antiseptic precautions and permanent dressings then applied, and, when necessary, the wounds are enlarged, drained, and disinfected. Those who have thus been dressed antiseptically are then transported to a permanent hospital. During transportation injured portions of the body, especially gunshot fractures, must be immobilised as thoroughly as possible (see § 53 and page 220).

In addition to permanent buildings, such as schoolhouses and churches, tents and the so-called Döcker's barracks are particularly well adapted for quarters for the wounded. Haase states that an army of 100,000 men needs 601 movable and 167 stationary barracks to furnish room for from 15,000 to 18,000 wounded. Some of the barracks used for war purposes are made of felt (Döcker's barracks), while others are tents or wooden sheds. Haase is right in recommending that these tents and barracks be put in position by bodies of men organised for that purpose and under the command of special officers. In a future war the tents will play an important part in the care of the wounded. The tents, in case they are used on the battle-field, can be made from the portable tent supplies of the soldiers, or they can be transported by rail to the points where they are to be put up.

We have not space to take up more in detail the first treatment of the wounded on the battle-field, but whoever is interested in this subject should consult the books which have been written upon it by Esmarch and Port. A very excellent and exhaustive treatise on military surgery will be found in Fischer's Handbuch der Kriegschirurgie

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(Deutsche Chirurgie, Stuttgart, 1882). For a description of the easily transportable operating table which I have devised for military practice, see page 7, Figs. 5 to 7.

Search for a Bullet.—In searching for a bullet one may use the disinfected finger or an ordinary probe, and in the case of very deep wounds, long, curved or straight dressing forceps, silver catheters, etc. Graham Bell has invented an electric probe for finding bullets. A needle which has been insulated by coating all but its point with varnish is inserted into the region where the presence of the projectile is suspected and then connected with the end of a telephone wire. A metallic plate of the same material as the needle is fastened to the end of the other wire and applied to the skin in the neighbourhood of the bullet. If the point of the needle comes in contact with the ball the circuit is closed, and every time they come together a distinct noise is heard in the telephone. Klein has constructed a similar electro-microphonic searcher (see Aerztl. Polytechnik, March, 1892). The magnetic needle can also be used in suitable cases for finding a ball even after it has become healed up in the tissues, and is especially applicable to the search for the modern steel-coated projectiles. Gärtner recommends that the steel-covered bullet which has entered the body be first magnetised by stroking the area in question with a powerful magnet. By means of a sensitive magnetic needle—i. e., a pair of astatic needles suspended by a silk thread, or Lamont's magnetoscope—the point on the skin is determined to which the ball or iron splinter lies nearest (Kocher, Gärtner, Sachs). Gärtner constructed an astatic magnetic needle out of a magnetised sewing needle which he broke in two, a straw, and a piece of silk thread, and made successful use of it in finding projectiles after having first magnetised them. The old-fashioned probe invented by Nélaton has a knob made of porcelain which is made black by contact with the bullet.

Fig. 465.—X-ray photograph of a right hand: *a*, pistol bullet between the fourth and fifth metacarpal bones.

Importance of the X-rays in Surgical Diagnosis.—The existence of this new form of vibration of ether was discovered by Professor Röntgen in

burg. Fig. 465 shows an X-ray photograph of the hand; the soft parts ɜrmeable to the Röntgen rays, while the bones, the ring on the fourth , and the bullet that is healed in between the fourth and fifth meta- ɜ are impermeable and stand out clearly. The X-rays are of great im- ıce in surgical and medical diagnosis, particularly for locating foreign ɜ in the tissues (needles, bullets, renal calculi, vesical calculi, etc.), and juries and diseases, and congenital and acquired deformities of bones ɔints. By the aid of the new improved apparatus the minute structure ɜ bone can be shown in a photograph. It would have much greater ostic value if it could show differences in the tissues of the various

6.—X-ray photograph of a left hand containing numerous pieces of lead. The patient ɜ wounded thirty years before in battle by splinters of lead from a bullet which struck gun.

ɜ. The X-rays have also been used therapeutically—for example, in the ıent of lupus and other skin diseases. After an experience of several with the X-rays we can say that, though they have not fulfilled the ıe expectations of the most sanguine enthusiasts, they nevertheless

occupy a permanent place as a valuable method of diagnosis, and every hospital should possess the necessary apparatus.

Projectiles are extracted by means of forceps, or spoon-shaped instruments. The most simple kind are the long, curved or straight dressing forceps, or long, narrow forceps with sharp-pointed teeth which cover one another when closed, so that they do not injure the tissues. The best-known spoon-shaped instruments are Thomassin's and Langenbeck's. Elevators can also be employed for this purpose. Formerly, if the ball were firmly embedded in the bone, it was extracted by screws or augers, which were bored into the lead like corkscrews. These augers and screws, and the forceps with the sharp-pointed teeth, are no longer used for the modern steel-coated projectiles, having been superseded by narrow, straight, or curved forceps. The steel-covered projectiles, however, remain lodged in the body much more rarely than the lead bullets; they usually pass entirely through it and emerge externally.

CHAPTER V.

TUMOURS.

Tumours in general.—Definition and classification of tumours.—Etiology of tumours.—Clinical features, diagnosis, prognosis, and treatment.—The anatomical structure and clinical course of the different varieties of tumours, with their treatment.

§ 125. **Tumours in General—Definition and Classification.**—The study of tumours forms one of the most interesting chapters of pathology; but it would require too much space to discuss this vast subject with anything like completeness, and so we must satisfy ourselves with merely a superficial account of such tumours and growths as are amenable to surgical treatment. Virchow has done more than any one else to advance our knowledge of tumours, and his work entitled Die krankhaften Geschwülste, will always be a glorious monument to German research. Other successful workers in this branch of pathology are C. O. Weber, Rindfleisch, Billroth, Thiersch, Waldeyer, Cohnheim, and Ribbert. For a description of the general pathology of tumours the reader is referred to the text-books of Cohnheim, Klebs, Orth, Ziegler, etc.

The question, What is a tumour? has received various answers. In fact, it is difficult to give a suitable definition which includes all tumours, as they present marked differences anatomically, etiologically, and clinically. Lücke's definition has been the most widely accepted. According to him, we mean by a tumour an increase in the volume of some portion of the body, due to a new formation of tissue which reaches no physiological limit, and which—to add Cohnheim's words—differs from the morphologico-anatomical type of the locality where it occurs. We distinguish from true tumours the hyperplastic, inflammatory formations, all the infectious granulation tumours of tuberculosis, syphilis, leprosy, etc., and certain collections of fluid and cells in preformed cavities, such as aneurysm, hygroma of tendon sheaths and mucous bursæ, hydrocele of the tunica vaginalis testis, and all retention cysts. We recognise, as Cohnheim does:

1. Tumours the main portion of which is of the connective-tissue type; these include fibroma, lipoma, myxoma, chondroma, osteoma, angeioma, lymphangeioma, endothelioma, lymphoma, and sarcoma, together with mixed or combination tumours made up of similar forms.

2. Tumours having the type of muscular tissue: Myoma lævicellulare and myoma striocellulare.

3. Tumours made up of nerve tissue: Neuroma and glioma.

4. Tumours of the epithelial type—viz., epithelioma, onychoma, adenoma, cystoma, and carcinoma. There remains as a subdivision of this group the teratoma of Virchow, in which many different kinds of tissue—such as hair, skin, bone, teeth, parts of intestine and brain—are found. In this class belong the dermoid cysts.

Birch-Hirschfeld makes the following classification: 1. Connective-tissue tumours; 2, muscle tumours; 3, nerve tumours; 4, epithelial tumours; 5, mixed or combination forms of tumours; 6, cystic tumours, consisting of a closed sac containing more or less fluid. This group includes tumours which are etiologically and histologically very different; some of them (retention cysts) do not belong to the proliferating tumours at all, while others are due to abnormities of development (teratoma-dermoid cysts), or originate secondarily from different tumours (cystoma glandulare, cystosarcoma). 7. Infectious tumours (granulation tumours) which are related histologically and etiologically to the inflammatory formations, and do not belong among the true tumours (products of tuberculosis, syphilis, leprosy, etc.).

§ 126. **Etiology of Tumours.**—The etiology of tumours, meaning thereby neoplasms, still remains obscure, although many theories have been advanced upon this subject. Their causes are partly direct and partly indirect or predisposing, the latter including the effects of age, sex, occupation, etc. Inherited predisposition plays an important part in their causation, and in many cases—notably of sarcoma—Esmarch believes that their development depends upon a predisposition inherited from syphilitic ancestors. As direct causes of tumours, local irritations—mechanical, chemical, or inflammatory in nature—have been thought especially important. Thus we know that a sarcoma, for instance, occasionally forms after a severe contusion, or that an epithelioma of the lower lip or of the mucous membrane of the mouth develops in immoderate smokers, or as a result of frequently repeated traumatic irritations caused by a sharp tooth, frequent shaving with dull razors, etc. Sometimes after fractures benign (osteoma, chondroma) and malignant tumours (sarcoma) develop in the callus—the so-called callus tumours. According to Rapok, one hundred and

twenty-eight out of six hundred and sixty-nine tumours followed injuries. Ziegler found that in 18 per cent. of his cases of tumours there had been a single traumatism, and in 25 per cent. a continued traumatic influence. Lowenthal found that out of 934 cases of mammary carcinoma a history of traumatism was present in 125, or 13.4 per cent. Out of 70 cases of sarcoma collected by Coley there were 44 in which traumatism played an important part in the etiology. In my opinion it has not yet been proved that a tumour can result from a traumatism, but it is undoubtedly possible, and this theory is in accord with our theoretical views regarding the nature of tumours. One could imagine that a traumatism separates larger or smaller groups of cells from their connection with the tissues, thus removing them from the physiological limits of growth and allowing them to develop a power of growth of their own and to displace the normal tissues (see page 812). In other cases tumours are caused by chemical and inflammatory irritation—e. g., carcinoma of the tongue in great smokers, and the carcinomata that develop in chimney-sweeps and workers in tar and paraffin factories. But chemical and inflammatory irritation is not sufficient in itself to produce a tumour. There must be a local predisposition to the development of a new growth, and this could be the same as in the case of traumatisms—i. e., the cells are separated by the inflammatory process from their physiological connections and after their displacement take on an independent growth. Sometimes disturbances of the nervous system—trophoneuroses—play an important part in their causation. Buchterkirch and Bumke saw a case of multiple, symmetrical lipomata which followed a contusion of the spinal cord. Symmetrical tumours have also been seen in the lachrymal and salivary glands. In a portion of these cases the swelling of the lachrymal glands which occurred first, and later that of the salivary glands, was inflammatory in nature. A preceding inflammation has a very important influence upon the development of neoplasms, as is shown in those cases of carcinoma of the breast which follow a mastitis. Malignant tumours, both carcinoma and sarcoma, often originate from simple warts, and melanomata from small patches of pigment in the skin. Rapok states that one hundred and eighty-two out of three hundred and ninety-nine carcinomata started in warts, and indeed one third of all the instances of tumours collected by him (six hundred and ninety-nine) had this origin. According to Woodhead, tumours are due to a deficiency—not a superfluity—of nourishment; even though there is actually an increased amount of food taken into the system, this is not able to supply the needs of the tissues in question. He holds the view that tumours develop when, as a result of irritations

from different sources—such as injuries, parasites, microbes, long-continued action of an irritating organic or inorganic substance, or a simple chronic catarrh—so great an increase in the activity of the tissue elements is demanded that the food brought into the system is insufficient to supply these demands. Schleich looks upon tumour-formation as a kind of infection originating within the organism, a cell at a certain stage of its physiological development becoming infectious as a result of irritations of various sorts. Analogously to the development of an impregnated ovum, tumours are considered by him as products of a pathological conception and impregnation; the pathological spermatozoon is represented by the cell that has become infectious. Many authorities think that tumours, particularly the malignant variety, are caused by micro-organisms (protozoa; see also page 819). Jürgens claims that there are some sarcomata which must be regarded as infectious, as they can be transmitted to animals by inoculation. Jürgens found sporozoa in both the primary and secondary tumours.

Cohnheim developed a very ingenious theory as to the ultimate cause of new growths. He thought this to be an abnormity or irregularity in the embryonic rudiment of the part of the body in question—in short, that neoplasms originate from the growth of embryonic germs or germinal cells which have been, as it were, shut up in the normal tissues. In many individuals these tumour germs do not become developed, but in others traumatisms, mechanical and chemical irritation, or the diminished powers of resistance possessed by the surrounding normal parts, increased blood supply, etc., may arouse them to activity. This theory of Cohnheim's seems very plausible for many cases, but it lacks anatomical foundation; in fact, as Birch-Hirschfeld says, a positive proof of the correctness of Cohnheim's hypothesis, as applied to tumours in general, is quite impossible. It is, however, unquestionable that some tumours spring from embryonic germs, and certain facts are very well explained by Cohnheim's theory—viz., the transmission of tumours by inheritance, the occurrence of congenital tumours, and of certain tumours in particular portions of the body, such as epithelial tumours, carcinomata of the lip, tongue, cardiac or pyloric orifices of the stomach, glans penis, cervix uteri, etc.; in other words, in localities where inversions of the epiblast in the form of groups of epithelial cells, which have strayed away during the embryonic period, may easily take place. Cohnheim's hypothesis also furnishes the best means of explaining the heterologous origin of primary epithelial tumours in organs which do not contain epithelium. We know, for instance, that the dermoid cysts are a result of stray embryonic germs. Ribbert has recently developed Cohnheim's theory more fully. According to him,

tumours are formed not only from strayed fœtal germs, but also from groups of cells that have become separated in post-fœtal life from their organic connections. We shall return to this theory under the subject of Carcinoma.

Transmissibility of Tumours.—Great importance attaches to the question whether or not tumours, especially malignant ones (carcinoma, sarcoma), are transmissible in the sense that living tumour-cells, when transplanted, can give rise to the development of the same kind of malignant tumour in that part of a body to which they are transferred. Such a transmissibility of tumours has in fact been sufficiently proved in the case of both animals and man by experimental and clinical observations. Eiselsberg successfully inoculated rats with a fibro-sarcoma. In regard to the transmissibility of carcinoma, see page 820; of sarcoma and melanoma, see page 806.

Etiology of Tumours in Animals.—Plicque and Fröhner have published, in regard to the origin of tumours in animals, some interesting facts which show many analogies to tumour-formation in man. The real cause of tumours in animals is, to be sure, unknown, as far as the predisposition of the bearer is concerned; but as regards the direct cause, the following has been noted: The carcinoma of the lip in horses generally develops in the corners of the mouth from pressure of the bit, while in cats the upper lip is ordinarily affected as a result of the repeated bites of small animals. The subcutaneous fibroma which is often seen in horses is caused by the pressure of the harness. Constant or frequently repeated traumatisms play an important part in the origin of tumours in animals, as do also preceding inflammations. Bitches suffer from carcinoma of the mammary glands much oftener than male dogs, and the hindermost glands are the ones most commonly affected, as they are particularly likely to be the seat of a mastitis. The melanosis of horses is thought to be transmissible by inheritance, so that mares or stallions which have it cannot be used for breeding; heredity is also said to play a part in the origin of the mammary cancer of bitches.

The influence of age is very noticeable in animals. In old dogs carcinoma is very frequent, while young ones are practically immune. Whether the nutrition of the animal plays a part in the tumour-formation, as has been thought to be the case in carcinoma in man, cannot, as Plicque says, be easily decided. Among pronounced carnivora, like the dog, carcinoma is very common, and herbivora like the horse are not exempt when they reach an advanced age.

§ 127. **Growth, Course, Diagnosis, and Treatment of Tumours.**—The growth of tumours takes place in exactly the same way as that of other tissues—by cell proliferation. The rapidity of growth is very variable, depending upon the locality, the blood supply, and the structure of the tumour. The more cells the latter has, the more rapidly it grows. Localised or more diffuse disturbances of nutrition, such as fatty degeneration, calcification, and colloid degeneration or necrosis, resulting,

perhaps, in a complete spontaneous cure of the tumour, very frequen occur. Necrosis in the form of ulceration is exceedingly comm especially in carcinomata which have broken through the skin mucous membrane. According to Nepveu and Verneuil, the soft ing of tumours is caused in some instances by bacteria. A true tum does not disappear spontaneously; some remain stationary, while ot keep on growing at a faster or slower rate. It is an interesting that, like fœtal tissues, tumours have a more or less abundant su of glycogen. The most important distinction between tumours is sented by their clinical course, and this allows us to divide them benign and malignant growths. The former remain local, but the latter penetrate into the neighbouring tissues and destroy them, and the tumour germs, being carried off in the blood and lymph, give rise to metastatic or secondary neoplasms in all parts of the system, especially the liver and lungs. Cartilage is the only tissue in which, so far as I know, no metastases have been found. The metastases have essentially the same structure as the primary tumours, and are found either in the vicinity of the latter—that is, in the region supplied by the lymph and blood which come directly from the tumour—or in distant organs after the tumour germs have passed through the heart. Metastases due to capillary emboli are most commonly caused by the tumour cells which pass through the lungs in the venous blood without being retained there (Zahn). Should the germs be carried through the lymph vessels, they usually become implanted in the nearest lymph glands and here lead to the development of tumour tissue which is identical with that of the original neoplasm. In this way the infected lymph glands become new foci for further infection and development of metastases. The tumour germs also enter the vascular system by a direct ingrowth of the mother tumour into the walls of the vessels. I once saw a metastasis in a valve of the femoral vein in a case of sarcoma of the leg. Tumours which in other respects are benign—such as fibroma, lipoma, cystic goitre, chondroma, myoma, etc.—may also, in exceptional instances, give rise to metastases. It is characteristic of tumour metastases—especially those from the really malignant tumours—to go on growing indefinitely. Normal tissue germs do not have this peculiarity, as is shown by the experiments of Cohnheim, Maas, etc. Small pieces of periosteum and embryonic cartilage implanted in the circulation, the peritoneal cavity, or in the anterior chamber of the eye, grow for a time and can thus give rise to very small osteomata or enchondromata; but these soon disappear without leaving any traces. If, on the other hand, living tumour cells from a carcinoma or sarcoma, for example, are inoculated upon animals, they go on developing, and

give rise to tumours which are the same as the original one. Man also may become infected with the germs of tumours, and this has occurred during operations for their extirpation. Carcinoma and sarcoma are the typical malignant tumours; they lead to local destruction of tissue and to general infection of the body by the formation of metastases. They are especially the ones which so commonly reappear at the original site after they have been extirpated. These recurrences are, according to Thiersch, due partly to tumour germs which were not removed, though in other instances we have to deal with a new tumour similar to the one that was removed, which makes its appearance in the cicatrix or near by, months or even years afterwards. Then, again, recurrences may be due to the inoculation at some point of living tumour cells during the extirpation of the primary tumour. It can easily be understood that a benign tumour may also prove fatal to the bearer on account of its position, as exemplified by an osteoma on the inner table of the skull.

The evil effects of tumours upon the organism are partly local and partly constitutional in character. Those in particular which grow rapidly are a great drain upon the system. The part which is affected may be entirely destroyed, and the formation of metastases, together with the necrosis and ulceration undergone by the tumour, may involve different organs and eventually lead to an increasing general cachexia, to which the patient will succumb. This cachexia, manifesting itself in the form of general disturbances of nutrition, loss of flesh, and marasmus, appears in malignant tumours which are accompanied by local destruction of tissue and metastases. It is probably caused mainly by poisons which are formed directly by the malignant tumours (see also page 823). Rommelaire and Ranzier have found that the excretion of urea is diminished in all malignant tumours, and may ultimately become less than twelve grammes *pro die*. The degree and rapidity of development of the cachexia depend upon the location of the tumour, its condition (ulceration, necrosis, hæmorrhage), and the age and constitution of the patient. The degree of malignancy varies considerably. Some malignant tumours, like epithelioma of the lip and the flat skin cancer (*ulcus rodens*), spread but slowly to the nearest lymph glands, while others—carcinomata and sarcomata, for instance—go on very rapidly to the formation of metastases in internal organs. The above-mentioned gradual diminution in the excretion of nitrogen, which is met with in malignant tumours, may occasionally have great value in determining the need and prognosis of surgical interference, especially if the decrease in the amount of urea is marked, in which case operative procedures are contraindicated.

The Possibility of curing Malignant Tumours (*Carcinoma and Sarcoma*).—A variety of statements, based upon statistics, have been published relating to the curability of the malignant tumours. Fischer and Meyer have written an especially interesting article on this subject. Of two hundred and ninety-eight cases of malignant tumours operated upon by Rose in the hospital at Zurich between 1867 and 1878, Meyer was able to get reliable returns from sixty-four. Of these sixty-four, twenty-two were alive in 1887 without recurrence, and showed a period of exemption varying from nine years and seven months to twenty years and three months. Nineteen died without recurrence, the period of exemption varying from one and a half to sixteen years. In the remaining five patients the cause of death could not be ascertained. Among the cases of cure were some exceedingly serious ones, involving very extensive operations, with removal of recurrent tumours and diseased lymphatic glands. Sarcoma, cysto-sarcoma, and fibro-sarcoma showed the longest period of exemption, while carcinoma showed the fewest instances of permanent cure. In rare cases of sarcoma of the skin and multiple melanosarcoma, spontaneous retrograde changes have been observed which have resulted in the complete and permanent disappearance of the tumours (Hardaway, author).

Diagnosis of Tumours.—The diagnosis of tumours is not always easy. By means of inspection, palpation, and examination of the subjective symptoms we try to form as correct an idea as possible of the location and structure of the tumour. The location of a neoplasm often enables us to determine its nature. Frequently a differential diagnosis must be made between an inflammatory process and a new growth (see page 252, Diagnosis of Inflammation). In doubtful cases puncture with a hypodermic needle may be necessary. It is important to determine before the operation whether the tumour is benign or malignant, in order to decide upon the kind of operation to pursue. In suitable cases—for example, in growths within the larynx probably carcinomatous in nature—parts of the tumour are removed and examined microscopically. Syphilis, tuberculosis, and other chronic infectious diseases must always be considered in making a differential diagnosis, as a large number of the connective-tissue tumours—such as certain so-called sarcomata of muscle, many spindle-celled sarcomata, neuromata, keloids, and malignant lymphomata (Esmarch)—are gummata, and can be cured by an antisyphilitic treatment. Some tumours, particularly the cystic variety, are translucent. This translucency can be made out by allowing the light from an electric lamp, for instance, to pass through the tumour.

General Treatment of Tumours.—The general rule in regard to the treatment of tumours—which we shall later discuss more fully in speaking of the individual tumours—is that they should be removed as quickly and as thoroughly as possible. The sooner a malignant tumour is radically excised the better is the prospect of a complete and

manent cure. The possibility of the total removal of a tumour ends upon its location and the kind of organ involved. In malig- t tumours, especially carcinoma, the neighbouring lymph glands uld also be removed, even though they are not diseased, and after ry amputation of the breast for carcinoma the lymphatic glands surrounding fat in the axilla must likewise be extirpated. The ıoval of tumours is accomplished usually by the knife, though occa- ıally by the galvano- or thermo-cautery, red-hot iron, ligature, *ısement*, etc., methods all of which have been sufficiently described §§ 24–44.

In proper cases Péan recommends the removal of the tumour in ;es (*morcellement*). The method consists mainly in first rendering tumour as bloodless as possible by the use of differently formed nps applied around its circumference, after which the growth is ised in portions, and, if possible, the wound is sutured while the nps are still in place. The latter can then usually be taken off and wound dressed. In other cases Péan leaves the forceps in position twelve to forty-eight hours. An almost bloodless operation can s be performed even in the case of very vascular tumours.

The encapsulated, myelogenic, giant-celled sarcoma of bone can in ;able cases be removed by cutting away only the anterior half of the ıy capsule by means of the chisel and hammer, or the saw, and then efully scraping out the tumour mass with a sharp spoon. Nussbaum lately made use of the thermo-cautery for the destruction of malig- ıt tumours like cancers. By circumcision with the thermo-cautery ;ases of inoperable, malignant neoplasms, the patient can be helped y materially; the growth of the tumours is thus diminished, the n caused to disappear, and any carcinomatous ulcerations are im- ıved and their decomposition checked. In cases of sloughing, in- ;rable carcinomata, the removal of the softened portions with the rp spoon and the subsequent application of the thermo-cautery give d results. In the case of inoperable ulcerating carcinomata and ;omata, the use of different caustics, in the form of caustic salves, example, is to be recommended.

Many attempts have been made to destroy tumours, especially in- rable sarcoma and carcinoma, lymphoma and myoma, by means of ;nchymatous injections of absolute alcohol, tincture of iodine, ›tine, acetic acid, nitrate of silver, arsenic, turpentine, osmic acid, sphorus, etc. Turpentine is injected with equal parts of absolute hol, or one part of turpentine to two parts of alcohol, from a half ı whole hypodermic syringeful about every ten to fourteen days. s is usually followed by the formation of abscesses which cause a

variable amount of shrinkage in the size of the tumour. Three drops of a one-per-cent. solution of osmic acid are injected every day. Arsenic can be given in the form of Fowler's solution, either internally or subcutaneously. Internally one begins with two drops daily, and increases the dose two to three drops every third day. About two drops of Fowler's solution, undiluted, are injected into the tumour daily, or ten drops of the undiluted solution once a week. The solution may be diluted two or three times for susceptible patients. A vigorous arsenic treatment is to be recommended in the case of inoperable carcinomata, and particularly sarcomata. Mosetig-Moorhof finds the parenchymatous injection of aniline dyes (pyoktannin, methyl violet, 1 to 500) very useful in malignant tumours (carcinoma and sarcoma), but the success which he has reported has not been experienced by other surgeons (Billroth); on the contrary, bad results, such as premature softening, breaking through of the skin, sloughing, etc., were obtained. In cases of inoperable tumours erysipelas has been inoculated by means of cultures of the erysipelas coccus, after Busch had observed that, as a result of erysipelatous inflammation, tumours, such as sarcoma of the face or neck, disappeared by fatty degeneration. Janicke and Neisser were able to demonstrate by microscopic examination, in a case of carcinoma with fatal erysipelas due to inoculation, that the cancer cells are actually destroyed by the erysipelas cocci. One should, however, take into account that such an inoculation may cause death, and hence one should warn the patient of the danger of the treatment. For a description of Emmerich's erysipelas serum in connection with malignant tumours, see page 824. A number of cases have been reported in which there has been improvement—usually a temporary one only—after the use of this serum (diminution in the size of the tumour, cessation of the pain, improvement in the general condition, etc.). Coley employs for sarcoma a mixture of the toxines of the streptococcus and *Bacillus prodigiosus*, which he injects into the tumour and into other parts of the body. The cultures are made in the same nutritive medium (bouillon); the *Bacillus prodigiosus* is added ten days later, and then in ten days more the combined culture is sterilised by heating it to a temperature of 58.6° C. Coley employs filtered cultures only in children and weakly individuals; they are from ten to fifteen times weaker than the unfiltered. He begins with the injection of 0.32 cubic centimetres. The action of the toxines upon malignant tumours, particularly sarcomata, is said to consist in progressive coagulation necrosis, with fatty degeneration. The method is only dangerous in case too large doses are used or the asepsis is faulty. Out of two hundred cases Coley lost

two in consequence of the treatment. This form of treatment should only be used in inoperable malignant tumours, and perhaps after the first operation, for the prevention of recurrences. Sarcomata, particularly of the spindle-celled variety, react best to the treatment; while in carcinomata no improvement was found to take place. Coley's method has been used by Bruns, Czerny, Richet, Fedorow, the author, and others, usually with negative results. Coley has reported on one hundred and forty cases of inoperable sarcomata which were treated by himself and others: out of eighty-four round-celled sarcomata, three were cured (period of cure one to three years); out of twenty-one spindle-celled sarcomata, ten disappeared entirely, and in three cases a recurrence took place after nine months to a year and a half. Melanomata were not cured. Peterson has reported the results in Czerny's clinic: out of twenty-seven cases (ten carcinomata and seventeen sarcomata) which were treated with Coley's serum, and seven carcinomata treated with the serum of Emmerich and Scholl, a marked degeneration of the tumour occurred in one case only (a sarcoma of the parotid). This tumour had been regarded as inoperable, but subsequently the portion that was left could be easily extirpated. In the other cases Czerny, like myself, observed only a temporary and partial softening in consequence of fatty degeneration of the cells, with œdematous infiltration of the tumour. In some cases the pain became less, the ulceration diminished, etc. Occasionally the breaking down in the central portion of the tumour is accompanied by increased growth at the periphery. The effects of the toxines upon the general system are sometimes dangerous; the cultures of the *Bacillus prodigiosus* have a deleterious effect upon the heart, and those of the streptococcus sometimes cause irritation of the kidneys. In a number of cases I observed high fever and marked emaciation. Richet and Hericourt have injected serum from animals inoculated with fluid obtained from sarcoma or carcinoma, and also serum from uninoculated animals which did not have as toxic an action. Both kinds of serum were found to cause only a diminution in the size of the tumours.

The man who succeeds in discovering a really successful method of treating malignant tumours—carcinomata, for example—would deserve to be honoured by humanity for all time as being its greatest benefactor.

§ 128. **The Different Varieties of Tumours.** *Connective-tissue Tumours; Fibroma.*—Of the different varieties of connective-tissue tumours, we shall first take up the fibroma, which is made up almost entirely of this kind of tissue. We distinguish ordinarily a hard (Fig. 467) and a soft (Figs. 468, 469) form. The hard fibroma is made up,

as a rule, of bundles of tough, coarse fibres with few cells, while the soft form consists of loose connective tissue having a great number of cells. There are, of course, numerous transition forms. The soft fibroma (fibroma molle) is also called fibroma molluscum (Figs. 468, 469, 470). The vascularity of the fibromata varies greatly, being sometimes very slight, and again so marked as to give rise to large dilatations of the blood and lymph vessels, as in the diffuse hyperplasia of tissue found in elephantiasis. Fibroma molluscum must not be confounded with the so-called molluscum contagiosum (see page 809).

Fig. 467.—Hard fibroma of the skin of the nose (Billroth).

The retrograde changes that take place in fibromata are fatty degeneration, calcification, softening, the formation of cavities and cysts, and a perforation of the skin with the formation of ulcers as a result of long-continued traumatic irritation from without, and of inflammation leading to the formation of abscesses. The fibroma only becomes dangerous from its location and size, the latter being sometimes very great, particularly in the case of fibroma of the skin or uterus (Fig. 470). In other respects the fibroma is a perfectly benign neoplasm, giving rise to no metastases, although it is found multiple, especially in the skin, where it may appear in vast numbers. The multiple fibromata of the skin (Fig. 470) may be the size of a pea or walnut, or they may grow and form very large soft tumours; they are sometimes accompanied by disturbances of the general nutrition (so-called leontiasis, Virchow). I cannot discuss here the question (see § 85) whether in such cases we do not really have to do with leprosy. According to the investigations of Recklinghausen, the multiple soft fibromata of the skin develop particularly from the connective-tissue sheaths of the sebaceous glands, vessels, and nerves (neurofibroma). Many soft fibromata are diffuse, hyperplastic formations, and represent a transition to elephantiasis, as seen in Fig. 468. These formations are sometimes called cutis pendula or elephantiasis of the skin. There are also observed in some

Fig. 468.—Soft fibroma of the face (elephantiasis faciei) of a twenty-four-year-old woman (Schuller, Griefswald clinic).

ses pigmentations which take the form of congenital moles, or of own discolorations with a growth of hairs (see Angeioma, page 790). any of the soft fibromata are transition forms of angeiomata, cavernnata, and lymphangeiomata. Just as in the skin, there are also und in the internal organs diffuse fibromata, which in these strucres likewise develop from the connective-tissue sheaths, especially of e glandular ducts and vessels; among these is the intercanicular oroma of the mammary gland.

Keloid.—In speaking of the hard fibromata, mention should be ade of the keloid, i. e., a tumour-like, fibrous degeneration of the

FIG. 469.—Soft fibroma of the right arm and chest in a man forty years of age (Byrom Bramwell).

in and subcutaneous tissue in the form of a tough swelling which nds out cord-like processes into the healthy surrounding parts. In far the majority of cases the keloid develops within a cicatrix catricial keloid). We distinguish, as do Warren, Kaposi, Denériaz, d others, three forms of keloid: (1) a spontaneous, (2) a cicatricial loid, and (3) the hypertrophied cicatrix. Scrofulous, tubercular, and philitic individuals seem especially prone to keloid. Denériaz is dissed to think that keloid is caused by infection with microbes. It is aracteristic of keloid to recur almost invariably after extirpation. loir and Vidal recommend, in true keloid, multiple scarifications, ich should be made in different directions during several sittings,

and followed by the application of a moist dressing with compresses wet in boric-acid solution, and on the next day of a mercurial plaster. Marie reports good results from the injection of 20 per cent. creosote oil.

FIG. 470.—Multiple soft fibromata of the skin (fibroma molluscum multiplex, Virchow) occurring on a forty-seven-year-old woman (Virchow).

Fibromata are most commonly found in the skin and subcutaneous tissue, in the nerves, periosteum, bone, uterus, and ovaries. Some of the polyps which form in the facial cavities—many nasal polyps, for example—are periosteal fibromata. There are sometimes seen, especially in the pharynx, polyps which are covered with hair and possess an epidermis, rete Malpighii, and corium, and, according to Arnold, originate from strayed embryonic cells. They belong, probably, to the teratomata (see page 828). Combination or mixed fibrous tumours include fibro-myxoma, fibro-myoma, fibro-sarcoma, fibro-neuroma, fibro-angeioma, fibro-cavernoma, fibro-lymphangeioma.

The diagnosis of fibroma can be easily made from what we have stated in describing the neoplasm.

Treatment of Fibroma.—The treatment of a fibroma consists in its removal by the knife, the galvano-cautery, or the thermo-cautery. Large diffuse fibromata of the skin are to be extirpated in several sittings by cuneiform excisions followed by deep sutures. Billroth once removed a large tumour in twenty sittings. I removed an extensive diffuse fibroma involving almost the entire scalp in one sitting, and covered the surface of the wound with Thiersch skin grafts. In cases of very large fibromata of the uterus one must often give up all idea of extirpation, and use injections of ergotine, or, in order to stop the frequent hæmorrhages, remove both ovaries (Hegar). The description of operations for fibroma of the uterus, etc., is found in the Regional Surgery.

Fibromata of nerves can usually be removed and the continuity of

the nerve preserved (see Neuroma). If the nerve cannot be saved, the nerve stumps can sometimes be united after the extirpation of the tumour by suture, or by the use of the neuroplastic methods described on pages 484–487.

Myxoma.—The myxoma is made up of a soft, gelatinous tissue. The microscopic examination shows the presence of a mucoid ground substance with a fibrillar framework and round, spindle-shaped or star-shaped cells. The latter have usually many branches and processes which interlace with one another (Fig. 471). Köster has denied that the myxoma is a special form of tumour, and, as a matter of fact, it is possible to look upon it as in the main a softened, œdematous fibroma or lipoma (myxo-fibroma, myxo-lipoma). Myxomatous, softened areas are often found in cartilaginous tumours.

The myxomata are met with most commonly in the skin and subcutaneous tissue, in the periosteum, medulla of bone, fasciæ, muscular sheaths, nerves, and in the brain and its coverings. The myxoma is, generally speaking, a benign tumour, but metastases and transitions to sarcoma do occur. They sometimes attain a very large size.

The treatment of a myxoma consists in its removal according to the above rules.

Lipoma.—The lipoma (fatty tumour) is a lobulated tumour made up of fatty tissue, sometimes soft and sometimes firm in consistence. The lipomata are either circumscribed or diffuse growths, and frequently possess a pedicle. According to their location, there may be distinguished cutaneous and subcutaneous, subserous (subperitoneal), subsynovial, submucous, and inter- or intramuscular (subfascial, peritendinous) lipomata. The lobes of fat of which the lipoma is made up are usually held together by bands of connective tissue. Increased development of the stroma gives rise to the lipoma fibrosum. In some instances, especially in the region of the neck and shoulder, very diffuse lipomata are found. Growth of the fatty villi in the joints, of which the knee is a prominent example, gives rise to the lipoma arborescens. Similar diffuse lipomata are found on the tendon sheaths. The articular lipomata probably develop as a result of traumatic ruptures of the synovial membrane, causing a prolapse of

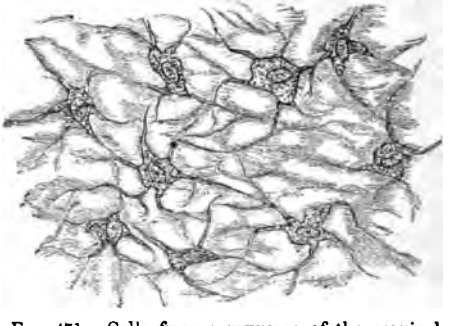

Fig. 471.—Cells from a myxoma of the cervical fascia. × 350.

the retrosynovial fat into the joint; they are also encountered in arthritis deformans, chronic rheumatism, syphilitic arthritis, etc. The lipoma arborescens of joints sometimes forms a transition to fibroma arborescens (Sokoloff). The subperitoneal and submucous lipomata which develop upon the stomach and intestine are of special clinical importance. The lipomata of the intestine occasionally give rise to intestinal obstruction. According to Sutton, two forms of lipoma are found attached to the spinal cord. In most cases they are the result of the change of the sac of a spina bifida into fatty tissue; less frequently they are intradural lipomata which grow around the spinal cord. The lipomata, as we remarked before, sometimes change into fibromata, myxomata, sarcomata, and cavernous tumours. They may attain an enormous size, especially when situated on the back, and growths of this kind, weighing twenty to forty pounds, have been successfully removed (Billroth, Hahn, and others). Pick published an account of a subserous lipoma of the abdomen weighing twenty-nine pounds. The lipoma is a benign tumour, and does not give rise to metastases, though it is sometimes multiple. As many as thirty to forty lipomata have been observed on different parts of the body, particularly in fat individuals. They are most likely to develop in individuals from thirty to fifty years of age, but are sometimes congenital, in which case they are usually diffuse, often combined with telangeiectases, dermoid cysts, and fibromata, and occur principally in the lumbar region and on the buttocks. The so-called "false tail" is merely a congenital lipoma pendulum which is situated above the anus, and may occasionally be combined with spina bifida (Bartels).

FIG. 472.—Lipoma of the back, weighing fifty-six pounds, in a man sixty-one years of age. Excision, followed by death from sepsis some days after the operation.

Quite recently Grosch has published the results of very exhaustive studies on this tumour, which place the seemingly simple lipomata in a new light. He has attempted to show that certain tumours are prone to develop upon particular parts of the body, mainly on account of definite anatomical condi-

tions and structural peculiarities which these parts possess. The lipomata appear to have a specially marked tendency to grow in certain localities, being most common on the front and back of the neck, on the posterior aspect of the trunk, about the shoulder, and on the upper and lower extremities. They are seldom encountered on the head, and then more often on the face than on the scalp, being rarest in the latter region (König, Gussenbauer). Grosch states that they occur most commonly in the integument of those parts of the body which have a scanty covering of hair and a small number of sweat and sebaceous glands. These glands eliminate fats and their derivatives in addition to disintegrated products of metabolism, and hence the amount of their secretion is an important index of the amount of the subcutaneous fat. Obesity and lipoma formation are, according to Grosch, quite identical. In many cases, particularly in thin individuals, the lipomata are neuropathic in nature, and possibly are the result of a diminution in the secretion of the sebaceous and sweat glands due to disturbances in the central nervous system. Symmetrical lipomata, in particular, result in this way.

The diagnosis of a lipoma is made chiefly from its soft, movable, lobulated character. If pressure is exerted upon the tumour, as a rule there will be felt a distinct crepitation caused by the crushing of single lobes of fat. The skin over the lipoma shows little shallow depressions which are particularly plain when the tumour is encircled by the hand.

The extirpation of lipomata by the knife and scissors is very easy even in the case of large tumours. In the case of large pedunculated lipomata it may be advisable to tie rubber tubing about the pedicle or apply a clamp for the purpose of arresting the hæmorrhage more effectually.

Fig. 473.—Small-celled chondroma of the finger. × 80.

Fig. 474.—Large-celled chondroma of the pelvis very rich in cells. × 80.

Chondroma or Enchondroma. — The chondroma consists essentially of cartilage, most commonly hyaline, less often fibrous or reticular. The cells which this kind of tumour contains may be small (Fig. 473) or large (Fig. 474), and their quantity varies within wide limits. The enchondromata are most often encountered in places where cartilage normally exists—hence, upon the skeleton (epiphyses, periosteum, medulla of bones)—though they are also met with in the parotid and thyroid glands, mamma, and testicle. The enchondromata of the skin and internal organs develop partly from stray cartilage cells and partly from trans-

formed connective-tissue cells, especially the endothelia of the connective-tissue sheaths and of the blood and lymph vessels. Thus chondro-endotheliomata are sometimes seen. The enchondromata which grow directly from cartilage—that of the epiphyseal line, for example—are also called ecchondroses. Like the exostoses, the enchondromata are often multiple, and appear in great numbers. Very remarkable cases of multiple enchondromata of different bones, combined with venous angeiomata of the soft parts, have been described by Kast, Recklinghausen, and others. Probably both kinds of tumours were the result of disturbances of circulation or of an abnormal congenital displacement of tissue cells. The angeioma formation might, however, be a secondary manifestation. Enchondromata are comparatively often the seat of degenerative changes, such as myxomatous softening and cyst formation. The most important mixed forms of chondroma are the osteochondroma and chondrosarcoma. Chondromata may eventually become entirely ossified. I have also seen a chondroma combined with a melanosarcoma—on the hand, for example. The simple enchondroma is in general a benign neoplasm, but malignant forms with metastases do occur. It is most often found in young subjects. The tumours attain at times a very considerable size, especially when situated upon the pelvis or the femur. A favourite locality for enchondromata is the fingers, where they form characteristic nodular tumours (see Fig. 475). They may also originate from cartilage cells in the ethmoid bone, and grow as an osteochondroma or cartilaginous exostosis into the frontal sinus and nasal cavity. These osteochondromata or exostoses of the frontal sinuses and nasal cavity can become detached, and are then found in these cavities in the form of free bodies or dead osteochondromata or osteomata. I have published a typical case of this kind. The frequency with which enchondromata or ossified chondromata (exostoses) of the ethmoid bone occur can be explained by the fact that remnants of the cartilaginous cranium remain in this locality for a comparatively long time. Degenerative changes—i. e., cystic softening of enchondromata—sometimes give rise to chondrocystomata, chondrofibrocystomata or osteocystomata, which resemble sarcomata somewhat clinically, but are usually perfectly benign and can be completely cured by extirpation (see page 788).

Fig. 475.—Enchondroma of the fingers of the left hand of a twenty-year-old spinner (Leo).

The location and the hard nodular consistency of the tumours are portant factors in making the diagnosis. The treatment consists in ir prompt removal with the hammer and chisel.

Osteoma.—The osteoma is a tumour made up of bone, and occurs ; only upon the skeleton, but also in the skin, muscles, tendons, gs, parotid gland, and brain. We have already spoken of diffuse l circumscribed osteomata — the perostoses and osteophytes — in nection with inflammations of ne (see page 644), and of the so-led "riding" or "exercise" bones ich develop in the muscles (see ge 571), and of the diffuse forma-n of bone which takes place in ositis ossificans progressiva (see ge 572). The development of bone tissues where bone is normally not sent is caused by cells of carti-e, periosteum, or marrow, which have strayed during fœtal life or ve become separated by traumatism. Osteomata also frequently pear upon bones after fractures. I once successfully removed such one, almost as large as a fist, from the horizontal and descending nus of the pubic bone, where it had followed a fracture. M. Lange reported an interesting case of multiple exostosis formation caused an ossifying myositis due to multiple fractures of both femurs and the pelvis (see page 607, Fig. 403).

Fig. 476.—Exostosis of the femur (Busch).

The osteomata situated on the surface of bones are also called *exos-es* (Fig. 476), and those in the interior of bones *enostoses*. The exos-es which are developed in the periosteum are sometimes very mov-e, and do not have a direct connection with the bone. Their struc-e is in some cases as compact as ivory (osteoma eburneum), and in er cases spongy (osteoma spongiosum). Many osteomata have a vering of cartilage (exostosis cartilaginea), and this is especially true the exostoses in the neighbourhood of the epiphyseal cartilage, which really ossified enchondromata or ecchondroses (ecchondrosis ossifi-is). The cartilaginous exostoses (osteomata with a covering of hya-e cartilage) are sometimes styloid or finger-shaped, and resemble a tacarpal or metatarsal bone. These cartilaginous exostoses, or rather ified chondromata, are often multiple, occurring in the neighbour-od of the epiphyses of many different bones in the same individual. casionally the influence of heredity is very noticeable. Heymann served multiple cartilaginous exostoses on many of the bones of a

phthisical patient whose mother and four brothers, as well as his three children, all had a similar peculiarity. Reinecke collected thirty-six cases of multiple exostoses from literature, in which the hereditary predisposition could be traced back in one case five generations, in fifteen cases three generations, and in twelve cases two generations. In such instances the development of the exostoses is due to an inherited predisposition, and begins usually in the third or fourth year of life. In rare cases these multiple cartilaginous exostoses that are found on different parts of the body disappear gradually of themselves, while others remain unchanged (Hartmann).

By *exostosis bursata* is meant an exostosis which is covered by a bursa. It develops principally in the joints, from the articular cartilage, and pushes the synovial membrane before it. The pocket thus made in the capsule of the joint either remains open, so that the bursa retains its connection with the joint, or it becomes entirely cut off from the latter (see page 718). These bursal or synovial exostoses generally contain a fluid resembling synovia, and several free-joint bodies usually made up of hyaline cartilage. This form of exostosis may also occur at some distance from a joint, and even upon the bones of the trunk and ribs; in these cases the enveloping sac forms after the fashion of an accessory, mucous bursa. The exostoses can become gradually or suddenly detached by traumatisms, for example, and then persist as dead pieces of bone, like the free dead osteomata in the frontal sinuses and nasal cavity.

Osteomata of the teeth and alveolar processes are comparatively common. The tumours of the teeth, the so-called odontomata, which consist of dentine and enamel, arise from the pulp or degenerated embryonic tooth cells as a result of anomalies during the period of development of the teeth, and sometimes in young subjects after injuries. The true odontomata are rare, and are found, according to Heath, almost exclusively on the lower jaw. They are sometimes formed from strayed dental germs, and can then develop in a large bony cavity, so that necrosis of the bone with an inclosed sequestrum is suspected (Krogins). Metnitz has published an account of five cases of this rare form of tumour, and thinks that want of room, abnormal position of the neighbouring teeth, and inflammatory processes, especially chronic periostitis, are important factors in their etiology. In general, two

Fig. 477.—Osteosarcoma (osteoid, malignant exostosis) of the superior maxilla (Busch).

forms of odontoma can be distinguished—soft and hard—or, better, those with dentine and those without (Partsch). The exostoses which form on teeth are, of course, not to be counted among the odontomata, but among the osteomata.

The osteomata are, on the whole, benign tumours, and usually grow slowly, but sometimes are found multiple, occurring, for example, on numerous epiphyses, where they are capable of causing disturbances of growth. In cases of multiple exostoses of the bones of the cranium and face, atrophy of the latter has been observed as a result of interference with its development. The malignant osteomata include the osteosarcoma, also called osteoids (see Fig. 477), which give rise to extensive local destruction of tissue and to metastases (see sarcoma). In this category belongs also the very vascular (pulsating) osteosarcoma. For cysts of bone, see page 825.

Fig. 478.—Congenital telangiectasis (birth-mark) with hairs (Mason).

Pointed exostoses can sometimes cause injuries to large arteries and veins, and thus lead to the formation of aneurisms, as in the instances observed by Boling, Küster, and others. In Küster's case a pointed osteophyte wounded the popliteal artery and led to the formation of an aneurism. After removal of the osteophyte by a chisel, and double ligation of the popliteal artery, a rapid recovery was made. Krönlein observed, on the other hand, that a traumatic aneurism of the popliteal artery which had lasted ten years caused an erosion and formation of osteophytes on the lower end of the femur.

The diagnosis of osteomata can usually be made from their location and hard, bony consistence.

Osteomata are usually removed by the chisel or saw, or, when in the soft parts, by extirpation with the knife. In cases of exostoses in the vicinity of a joint one should always think of the possibility of their communicating with the joint. In such cases the tumour is only removed when it causes serious trouble.

Angeioma (*Blood-vessel Tumour*).—The *angeioma* is made up principally of newly formed and old, dilated, hypertrophied blood-vessels. Ribbert claims that angeiomata are limited to the blood-vessels in which they first develop—i. e., they grow by enlargement of the original tumour, and not by involving neighbouring capillaries. Three varieties are distinguished:

1. *The angeioma simplex* (telangeiectasis, nævus vasculosus, plexiform angeioma) consists of dilated, tortuous, and newly formed capillaries and small vessels. Macroscopically, the telangeiectases are mostly soft swellings, bright- to dark-red in colour, which are only slightly elevated above the surface of the skin, where they are usually found. The origin of the cells of the nævus is given differently by different authorities. Unna claims that they originate from the epithelial cells, and others regard them as connective-tissue cells. Nævi are very often congenital, forming the so-called birth-marks. Multiple nævi often have a special distribution over the body, and are then thought to be caused by intrauterine disturbances of trophic or vasomotor nerves or by disturbances of development in certain areas of the skin. These birth-marks are often associated with hypertrophy and pigmentation of the skin, and very frequently with hair-formation (see Figs. 478–481). Many of these hairy birth-marks are diffuse, soft fibromata, others more like telangeiectases. The hair-formation often resembles the hide of animals, such as rats, monkeys, or rabbits. The mothers of such children often say—as in the cases illustrated in Figs. 478, 479—that they were frightened during pregnancy by the sudden appearance of the animal whose skin resembles that of the birth-mark. The marked heteroplastic development of hair on certain parts of the body which are covered with an otherwise normal skin—the growth of a beard in women, for example (hypertrichosis circumscripta)—and the growth of hair over the entire body (hypertrichosis universalis), have nothing to do with tumour-formation; it is mostly a hereditary malformation which is found in certain families. Several families of hairy people are known in which the complete covering of the body with hair was inherited by the children. Fig. 480 represents Schwe-Maong, the father of an Asiatic hairy family, and Fig. 481 the Russian hairy man Andrian, whose son had the same peculiarity. Treatment by the galvano-cautery may be used for this abnormity.

Fig. 479.—Very large congenital hairy birth-mark on the back, neck, and upper extremity of a twelve-year-old girl (Beigel and Paget).

2. The angeiomata also include the aneurysma anastomoticum or racemosum, which is best called angeioma arteriale racemosum or cirsoid aneurism, and has been described in a previous chapter (Fig. 482). The cirsoid aneurism, as we saw on page 555, is the result of

iniform dilatation, tortuosity, and thickening of the arteries ıg a certain region, and is due partly to the formation of new ınd partly to hypertrophy of the old ones.

'he *cavernous angeioma* (tumor cavernosus) resembles in struc- ɜ corpus cavernosum—i. e., it consists of cavities lined with lium, which are filled with fluid or coagu- .ood, and separated by connective-tissue It is most commonly found in old people liver, skin, or subcutaneous tissue; less the brain, spleen, kidneys, uterus, or bone. ws as to its origin do not agree. Accord- Rokitansky, the cavernous spaces are first from the connective tissue, and then sec- · become joined with the blood-vessels s filled with blood. Another explanation › me the more probable, viz., that a dila- f the capillaries first takes place, and sub- ly the walls of the dilated capillaries which lie next one another .y disappear, resulting in the formation of large cavities filled ›od.

FIG. 480.—Shwe-Maong, ancestor of an Asiatic hairy family.

'eioma is not infrequently combined with fibroma, lipoma, and . (angeiosarcoma).

treatment of angeiomata consists in their extirpation with the : possible, or with the galvano-cautery or thermo-cautery (so- gnipuncture or punctiform ustion). In order to operate with- out loss of blood, the base of the angeioma may in appropriate cases be transfixed and tied off in two or more parts, or portions of the tumour may be seized by clamps before they are divided. Billroth applied two perforated lead plates to the base of the tumour, which were joined by silver wire drawn tight, thus making an artifi- cial pedicle which allowed the tumour to be removed almost without loss of blood. In other instances he applied a chain su- ture—i. e., the tumour is lifted up, clamped at its base, and underneath the clamp in- terrupted sutures are applied in such a t every suture takes in a small part of the tissue that is included previous suture. Large, diffuse angeiomata, like cirsoid aneu- ıay, if removal is impossible, be treated by ligation of the affer-

-Andrian, a Russian hairy Virchow and Bartels).

ent arteries combined with ignipuncture. Cirsoid aneurism occurs most commonly on the scalp, and in this situation might require ligation of the external carotid. If the main artery is too short, each of its branches should be secured. It is dangerous to ligate the common carotid on account of the changes which may thus be produced in the cerebral circulation. For the purpose of preventing recurrences it is often advisable to apply to the diseased part for a considerable time dressings which exert pressure, or to paint it with iodoform collodion. Nævi which cover a large surface or are very numerous and cannot be extirpated can be successfully treated by Mikulicz's method. The epidermis and uppermost layer of the corium are removed with a microtome knife under strict aseptic precautions. It is absolutely essential to avoid suppuration; a dry dressing is applied, which is kept on for two to three weeks until cicatrisation has taken place. In some cases the operation is performed at several sittings three to four weeks apart. Among other methods which have been recommended are electrolysis, parenchymatous injections of the tincture of iodine, liquor ferri subsulphatis (Monsell's solution), absolute alcohol, liquor Piazza (sodii chlor. 15.0 grammes; liq. ferri sesquichlorati [thirty per cent.], 20.0 cubic centimetres; aq. destil., 60.0 cubic centimetres [St. Germain]). Care should be taken not to make the injection into healthy subcutaneous tissue. Gunn and Haven speak well of the injection of carbolic acid (ninety-five per cent. acid. carbol. and glycerine, āā) into the peripheral parts of the angeioma (a few drops in from five to fourteen different places). Setons made of threads saturated in liquor ferri subsulphatis, and then dried and passed through the growth, used to be employed, as were also ligation (see page 78), cauterisation with fuming nitric acid, etc. These are all methods of treatment which have now become obsolete.

FIG. 482.—Angeioma arteriale racemosum (cirsoid aneurism) of the arteriale angularis and frontalis dextra et sinistra of a twenty-year-old man (Bruns). Ligation of the right external carotid and left common carotid. Death due to cerebral embolism.

Lymphangeioma (*Angeioma Lymphaticum*, *Lymphangeiectasis*).—The lymphangeioma corresponds to the angeioma of the blood-vessels, and consists essentially of dilated and hypertrophied lymph vessels (Fig. 483). The following varieties may be distinguished: 1, lymphangeioma simplex (telangeiectasia lymphatica); 2, cavernous (lymphangeioma cavernosum) (Fig. 483); and 3, cystic lymphangeioma (lymphangeioma cysticum). Some lymphangeiectases are acquired and others are congenital. According to Ribbert, lymphangeioma is an independent, self-limited tumour made up of connective tissue and lymphatics, in whose growth all the tissue elements take an equal part. Lymphangeiectasis, on the other hand, is not an independent circumscribed formation; the dilatation occurs in vessels which are normally present in a tissue. With the dilatation there is a simultaneous thickening of the walls. The great majority of lymphangeiomata are probably due to disturbances of embryonic development; a simple lymph stasis would not be sufficient to explain them, although it can favour the growth of a lymphangeioma which already exists, and particularly the formation of cysts. In the formation of epithelial cysts the proliferation of the connective tissue and the enlargement of the cavities take place at the same time. The lymphangeiectasiæ usually communicate directly with the lymph vessels, and in one case Nasse was able to demonstrate an open connection between a cavernous lymphangeioma of the neck and the subclavian vein and thoracic duct—a circumstance which can only be explained on the grounds of a disturbance of embryonic development, as mentioned above.

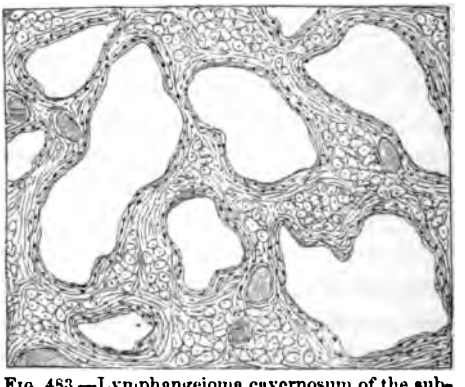

Fig. 483.—Lymphangeioma cavernosum of the subcutaneous cellular tissue of the neck, consisting of enlarged lymph vessels with hypertrophic walls. × 30.

In consequence of this communication of a lymphangeioma with veins caused by abnormalities in fœtal development, large blood-cysts are formed, especially on the neck (Bayer). The congenital lymph-angeiectatic hypertrophy of the tongue (macroglossia) and of the lips (macrocheilia) belong to the congenital lymphangeiomata. Lymphangeiomata sometimes reach a very considerable size. The fluid which they contain is, as a rule, clear, but sometimes milky. Lymphangeioma is sometimes complicated by inflammatory manifestations. If one ruptures, a lymphorrhœa or lymph fistula results, through which large

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amounts of this fluid may escape (see page 564). Lymphangeiectases are very often found in connection with the diffuse hyperplasia of connective tissue forming the so-called elephantiasis (elephantiasis lymphangeiectatica, see page 540).

The treatment of lymphangeioma has already been spoken of. When possible, it consists in extirpation of the growth—a procedure which is sometimes very difficult. Simple incision and drainage, or packing with iodoform gauze, may prove effective in cystic tumours; but this method should not be used when numerous small cavities are present. Bergmann has obtained very good results from extirpation, and Rehn successfully removed a lymphangeioma cavernosum of the sacral canal which pressed upon the cauda equina.

Myoma (*Muscle Tumour*).—The *myoma* is made up essentially of muscle fibres, which may be either striated (rhabdomyoma, myoma strio-cellulare) or non-striated (leiomyoma, myoma lævicellulare, Fig. 484). Simple rhabdomyomata are very rare, the myosarcoma being the most common tumour of striated muscle. Striated muscle fibres and spindle cells with striations are often seen in sarcomata of the testicle, kidney, and in tumours of the ovary (myosarcoma). Probably in such cases strayed embryonic muscle cells have become deposited in these organs. The leiomyoma is most common in the uterus and intestinal tract, where it takes the form of nodular tumours, which are more or less pure myomata or fibro-myomata. Microscopically, the non-striated muscle fibres are recognised on longitudinal section by the rod-like nuclei and their regular arrangement. On cross section the characteristic contours of the fibres are seen, together with the transverse section of the nuclei, in their interior (Fig. 484). The leiomyomata of the uterus often take on secondary changes, such as extensive fatty degeneration, calcification, cyst formation, and suppuration. They are occasionally combined with sarcoma and carcinoma. Multiple myomata sometimes occur in the skin, originating from cutaneous muscular elements.

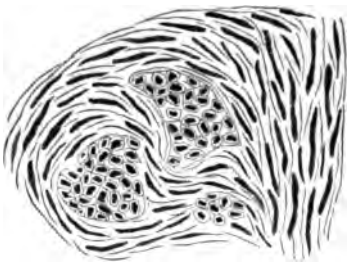

Fig. 484.—Leiomyoma of the uterus; some of the nuclei of the muscle fibres have been cut longitudinally, and others transversely. × 200.

The treatment of myomata—for example, of the uterus is in the main the same as that of fibroma (see page 782).

Neuroma (*Nerve-fibre Tumour*).—The *neuroma* is made up essentially of newly formed nerve fibres. A distinction is made between true and false neuroma. Most neuromata are false—that is, they are

fibromata or myxomata of the connective-tissue portion of nerves, with displacement and atrophy of the nerve fibres. They generally form flask-like swellings of the nerves, or cylindrical or spherical tumours, about the size of a bean, cherry, or plum, and, in rare cases, the size of a hen's egg. The false neuromata are often multiple. Bergmann, for instance, observed more than a hundred neuro-fibromata of the skin

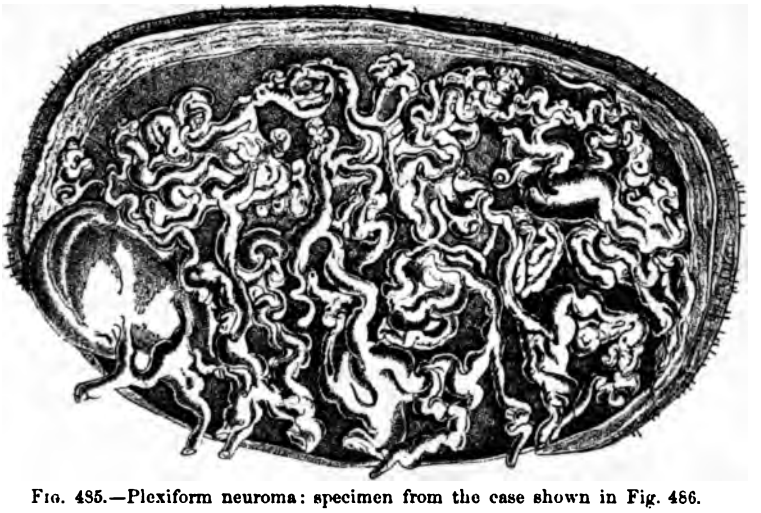

Fig. 485.—Plexiform neuroma: specimen from the case shown in Fig. 486.

in a man fifty-four years old. The so-called amputation-neuromata, which are club-shaped swellings of the ends of the nerves in amputation-stumps, are, as a rule, made up mostly of newly formed connective tissue, with more or less numerous collections of new nerve fibres. The so-called plexiform neuroma also belongs to the false neuromata or fibro-neuromata. It is essentially a nodular, fibrous degeneration of the branches of a particular nerve, the trunk of which becomes twisted and tortuous (Fig. 485). Instead of a plexus of strongly developed nerve fibres that have undergone fibrous degeneration, as shown in Fig. 485, we sometimes find a single large nerve trunk, with numerous branches, which shows at some points localised swellings—i. e., small fibromata, and is embedded in a gelatinous stroma (Tietze). These plexiform neuromata, of which the rudiments were present in the embryo, are very much like soft fibromata of the skin and subcutaneous cellular tissue, in which they form flabby, lobulated folds and elevations (Fig. 486), sometimes uneven and nodulated, usually containing dark pigment and covered with hair, as in elephantiasis (Fig. 468). Very large tumours sometimes result from this elephantiasis-like hyperplasia of the skin and subcutaneous tissue. The plexiform neuroma is almost

always situated in the subcutaneous tissue, and only exceptionally in the deeper parts, as in a case seen by Pomorski, in which a plexiform neuroma of the intercostal nerves had grown into the pleura. Bruns collected from literature a large number of instances of plexiform neuroma, and found that its most common location is on the temples and upper eyelid (fifteen cases). It was found eight times in that part of the neck which lies posterior to the ears, three times on the nose and cheek, four times near the lower jaw and front of the neck, seven times on the breast and back, and three times on the extremities.

Fig. 486.—Plexiform neuroma of the lower part of the face and neck, on the right side, in a boy ten years old (Bruns).

The *true* neuromata consist for the most part of newly formed nerve fibres, which develop in one or more peripheral nerves. Some cases of amputation neuromata also belong to this class of tumours. Depending upon whether the neuroma is made up of medullated or non-medullated nerve fibres, we make a distinction, as Virchow does, between a neuroma myelinicum and a neuroma amyelinicum. The brain and certain neoplasms of the testicle and ovary are sometimes the seat of a cellular (ganglionic) neuroma. The neuroma is in general a benign tumour, though it is sometimes multiple in the nerves of the brain and spinal cord.

In rare cases neuromata are found to be malignant, giving rise to local recurrences after extirpation, and even to metastases (Fig. 487). Garré distinguishes primary and secondary malignant neuromata; the former are chiefly the sarcomata of nerves, while the secondary malignant neuromata result from sarcomatous changes in a previously benign neuro-fibroma. The above-mentioned multiple neuro-fibromata also

undergo in some cases malignant changes; Garré has collected sixteen cases of this sort from literature. According to Goldmann, the malignant degeneration of benign neuro-fibromata depends not so much upon a change in the anatomical character of the tumour as upon changes in the entire organism. Histologically the primary malignant neuromata are usually medullary, round, and spindle-celled sarcomata, or dense fibrous neuromata, with nevertheless a very malignant course, or finally myxomata or lipomatous myxomata. Central softening and cyst formation are frequent. The malignant neuromata usually start from the nerve sheaths, particularly the intra-fascicular tissue (endoneurium). They may develop rapidly into tumours as large as a man's head, and occur particularly in the large nerves of the extremities—e. g., the median and sciatic—but not infrequently they start from small cutaneous nerve branches. Before metastasis takes place through the circulation, metastatic tumours are sometimes formed throughout the whole nervous system. Bünger reported a very characteristic case of general multiple neuro-fibroma formation in the peripheral nervous system and the sympathetic system which had developed after a neuro-fibroma of the external cutaneous nerve of the thigh. Newly formed medullated nerve fibres are occasionally found in the neuromata—a fact which is not remarkable, as we know that degeneration and regeneration of nerve fibres take place in normal nerves.

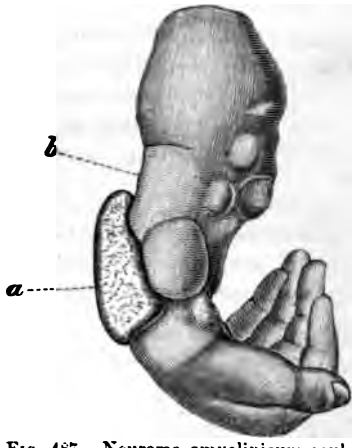

Fig. 487.—Neuroma amyelinicum multiplex recurrens ulcerosum antibrachii. Most of the nodules lie beneath the skin: *a*, ulcerating nodule; *b*, scar from a previous extirpation of the primary neuroma (Virchow).

The so-called tubercula dolorosa, which appear as small, movable, painful, subcutaneous tumours, are, according to Virchow, in some instances true neuromata, while in others it has not been possible to demonstrate nerve fibres.

As regards the treatment of neuroma, I may say that neuro-fibromata and neuro-myxomata can usually be removed and the continuity of the nerve be preserved. If extirpation is not possible, as in the case of large nerves of the extremities, for example, and the removal of the tumour is indicated on account of great pain, rapid growth, etc., the continuity of the nerve must be restored, after the extirpation of the neuroma, by means of sutures or a plastic operation. The treatment

of a plexiform neuroma, which involves the whole region of distribution of a nerve, is merely palliative in case extirpation is impossible.

Glioma.—Gliomata occur especially in the brain, less often in the spinal cord, and result from the growth of the neuroglia cells of the central nervous system. They form pale-grey, greyish-white, or, when very vascular, reddish or dark-red tumours, which are usually not sharply defined. They are not infrequently the seat of retrograde metamorphoses, such as fatty degeneration, caseation, and softening. Under the microscope the gliomata are seen to be made up of a network of fine translucent fibres, which contain branching cells resembling those of the neuroglia. According to Klebs, Heller, and others, many gliomata consist of growing ganglionic cells and newly formed nerve fibres. Ziegler is right in separating these from the gliomata, and calls them neuroglioma ganglionare.

Lymphoma.—By lymphoma we understand a true neoplasm as well as a chronic inflammatory or infectious hypertrophy of lymph glands. The latter may originate as a result of local and constitutional causes. In this category belong, for example, the lymphomata of the neck following chronic inflammation of the skin or mucous membrane in the region supplied by the lymphatic vessels which lead to the enlarged glands, also the lymphomata due to local or general tuberculosis, or which occur in the course of leucæmia, and the progressive lymphomatous formations encountered in anomalies of the organs producing the blood (malignant lymphoma, Hodgkin's disease, pseudo-leucæmia). The word lymphoma signifies, in general, hyperplasia of lymph glands, but if the enlargement is caused by a true neoplasm, we call it, according to its structure, a lympho-sarcoma, lymph-adenoma, etc. The above-mentioned progressive formation of lymphomata in Hodgkin's disease is exceedingly interesting. The disease usually begins with a large nodular swelling of the lymph glands of the neck (see Fig. 488) which is entirely free from pain. As a rule, the adjoining lymph glands become successively swollen, then the glands of the other side, and, finally, in many cases the mediastinal and retroperitoneal glands. The microscope shows a simple hyperplasia of the lymph glands, though Goldmann observed in them a marked increase in the number of cells which can be readily stained by eosin (eosinophilous cells). Metastases in the internal organs are of frequent occurrence

Fig. 488.—Soft malignant lymphoma of the neck and both axillæ in a boy six years of age.

(lungs, spleen, liver, kidneys, bone), and the enlargement of the spleen may become very marked. The general health can remain undisturbed for a comparatively long time, but ordinarily a steadily increasing loss of flesh and strength soon sets in and is followed by death. In the severe cases intermittent rises of temperature usually occur. Fischer found staphylococci in the blood during the attacks of fever, which had perhaps entered the circulation from the intestinal tract. In a number of cases a combination of malignant lymphoma with tuberculosis has been observed, the patients then dying of the tuberculosis. The latter is probably a secondary infection of the weakened organism. Occasionally, as in goitre, the end comes suddenly from suffocation in consequence of softening of the laryngeal cartilages or of paralysis of the vocal cords due to bilateral pressure on the recurrent nerve. The etiology of malignant lymphoma has not been thoroughly investigated. The white blood-corpuscles are not increased in numbers as in leucæmic lymphoma, hence the name pseudo-leucæmia. Malignant lymphoma or pseudo-leucæmia is probably the result of some as yet unknown infection. Transitions to lympho-sarcoma sometimes occur.

The treatment of lymphoma varies according to its cause. Neoplasms of the lymph glands should be extirpated as soon as possible. Tubercular lymphomata should also be treated in the same way, or scraped out with the sharp spoon, or treated by ignipuncture with the galvano-cautery, or parenchymatous injections of ten-per-cent. iodoform oil or iodoform glycerine, etc. I also excise simple, non-tubercular, so-called scrofulous enlargements in case they do not disappear under a general tonic regimen, a thing which is of great importance in the management of all lymphomata. In malignant lymphoma the arsenic treatment is sometimes successful, both internally and in the form of parenchymatous injections. Billroth began with ten drops of Fowler's solution *pro die* internally, and injected at first two, subsequently four to six drops a day into the substance of the tumour. The internal dosage may be raised two drops every third day, but if symptoms of poisoning make their appearance the doses must be diminished. A cure is not obtained in this way, but the patient improves and the course of the disease is checked or rendered less severe. The operative removal of malignant lymphomata is probably always unsuccessful, as recurrences appear, as a rule, very promptly. But they should be removed sufficiently to relieve at least the urgent symptoms, such as those caused by obstruction to respiration.

Sarcoma.—The sarcoma (Figs. 489, 490) is a neoplasm which springs from connective tissue, and is formed, in general, after the type of embryonic connective tissue with abnormal and luxuriant cell forma-

tion. The sarcomata originate in all varieties of connective tissue (cartilage, bone, periosteum, ordinary connective tissue, fat tissue, etc.), and are particularly likely to start from the cells of the walls of the blood-vessels. The etiology of sarcoma has recently been advanced by the very interesting investigations of Jürgens. The latter showed that some sarcomata are infectious in nature and can be inoculated upon animals; he found sporozoa both in the tumours and in the blood of the animals, which explains the early occurrence of metastases. The question whether all sarcomata are of parasitic origin cannot at present be answered (see also pages 816–821, Etiology of Carcinoma). Benign tumours, as we remarked before, not infrequently become sarcomatous, thus giving rise to mixed tumours, such as fibro-sarcoma, myxo-sarcoma, osteo-sarcoma, etc. Sarcomata in the skin, periosteum, and marrow of bone occasionally appear in a multiple form. The multiple sarcomata of the skin (sarcomatosis cutis) sometimes represent a transition from inflammatory growths to real sarcomata; they form a group of neoplasms separate from the latter, to which the mycosis fungoides also belongs (see page 544). The size and shape of the cells in a sarcoma vary considerably (Figs. 491–496), many being round cells, which are often contractile, like white blood-corpuscles, while others are spindle cells, endothelial cells, stellate cells, or giant cells. Between each of these there are numerous intermediate cell forms, and different shaped cells are often found lying next one another. There is a greater or less amount of intercellular substance which may be fibrous, homogeneous, reticulated, granular, mucoid, etc. The vascularity of sarcomata also varies very much, being occasionally so marked that the tumours pulsate like aneurisms. They likewise show

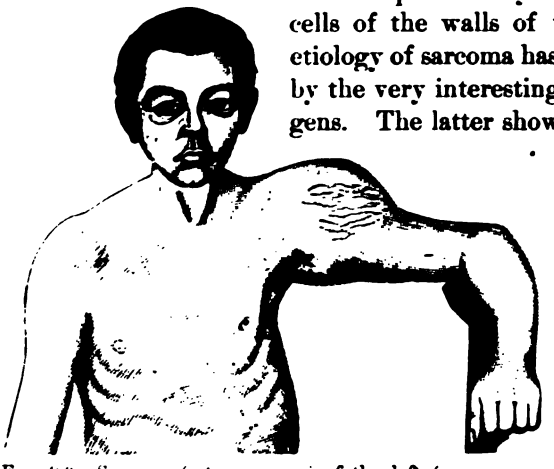

Fig. 489.—Sarcoma (osteo-sarcoma) of the left (upper) arm (Esmarch).

Fig. 490.—Sarcoma (myxo-sarcoma) of the dura mater in a twenty-eight-year-old man (Heineke).

ifferences in consistence and colour. The very malignant, soft, growing sarcomata, made up largely of cells, are especially to ded (medullary sarcoma). The pigmented varieties, the melano-ıta, are also very malignant. The formation of metastases takes .s Billroth showed, principally through the veins, and to a less through the lymphatics. I once found in a case of medullary a of the lower extremity a metastatic deposit the size of a small a valve of the femoral vein. trograde changes which take ıre fatty degeneration, casea-ftening, cyst formation, hæm-, and, after the disease has through the skin, ulceration ughing.

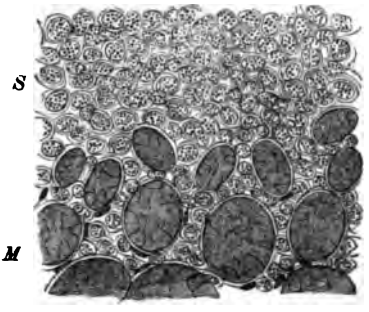

Fig. 491.—Marginal portion of an intermuscular sarcoma of the arm: S, sarcoma tissue consisting of round cells; M, transversely divided muscular tissue.

coma of bone originates either ıe periosteum or from the med-cavity. The latter, or myelo-ırcoma, is characterised by hav-greater number of giant cells. g as the central (myelogenic) a of bone possesses a closed the prognosis is favourable, but otherwise it is extremely bad. twelve patients with sarcomata of the long bones which were d with the knife, six died from recurrences, and of the remain-, two had to be operated on again very soon for recurrence. ing to the shape of the cells and the structure of the sarcoma the following different forms are distinguished, which of course often merge into and combine with one another to a greater or less extent:

—Portion of a sarcoma fascia of the thigh ing cells of various small and large round indle cells, polynucle-ant cells, etc.). × 250.

1. The *round-celled* variety occurs as the small- and large-celled sarcoma. The small round-celled sarcoma (Fig. 491) is made up of cells which resemble white blood-corpuscles, and as a rule grows rapidly, forming a soft tumour, which on section appears white, and when squeezed gives out a milky fluid. It consists of round cells, blood-vessels, and generally of a very small amount, of a fibrous, granular, or homogeneous In some cases it has a pronounced alveolar structure, and then re-gland tissue or carcinoma—i. e., the cells, or rather groups of cells, ided off by connective-tissue septa (alveolar sarcoma, Fig. 493). The ›und-celled sarcomata are usually very malignant in character; they

destroy the surrounding tissues, forming metastases and running a course similar to carcinoma (§ 129). The most common locations for this sarcoma are connective tissue, muscle, fascia, periosteum, bone, lymph glands, etc.

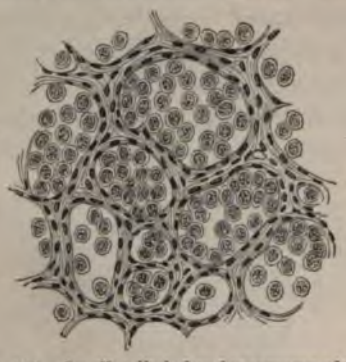

Fig. 493.—Small-celled alveolar sarcoma of the lymph glands of the neck. The alveoli between the connective-tissue bands are filled with sarcomatous round cells. × 150.

Fig. 494.—Large-celled sarcoma of the breast. × 300.

The *large round-celled sarcoma* (Fig. 494), although it is not quite so malignant as the small-celled and does not grow as rapidly, is very similar to the latter in its clinical course. It also occasionally possesses an alveolar structure.

2. The *spindle-celled sarcoma* usually consists of cells which are for the most part long, thin, and spindle-shaped, lying close together (Fig. 495), with or without a variable amount of homogeneous or fibrous intercellular substance. If the latter is fibrous and abundant the tumour is called a fibro-sarcoma.

Fig. 495. — Cells from a spindle-celled sarcoma of the thigh. × 300.

3. The *giant-celled sarcoma* is characterised by the presence of a great number of very large, polynuclear, round, or polymorphous cells (Fig. 496), and originates most commonly in bone marrow (myelogenic osteo-sarcoma). Giant cells are also occasionally found in the round and spindle-celled sarcomata, but not by any means in such quantities as in the true giant-celled neoplasm.

Fig. 496. — Cells from a myelogenic giant-celled sarcoma of the lower jaw. × 300.

4. *Stellate or reticular-celled sarcomata* are most commonly encountered in myxomata and myxo-chondromata which are combined with sarcoma. The stellate or reticular cells, with their interlocking processes, are usually embedded in a soft, gelatinous, mucoid intermediary substance.

5. In many sarcomata cells of all varieties of shapes are found together (sarcoma with polymorphous cells, Fig. 492).

6. The *alveolar sarcoma* (Fig. 493) which was mentioned above is made up of mononuclear and polynuclear cells, as a rule about as large as average-sized pavement epithelial cells, which lie singly or in groups in a fibrous, less often in a homogeneous intermediary substance. A characteristic feature of this variety is that the cells, contrary to carcinoma, are closely united to the connective-tissue stroma, and cannot be easily separated from the fibrous meshes. Although this forms the means of distinguishing the alveolar sarcoma from carcinoma, yet sections of the two tumours under the microscope often present such similar pictures that it is very difficult to recognise one from the other.

7. The *plexiform angeio-sarcoma* (Waldeyer) is to be looked upon as an angeioma with a sarcomatous growth of the walls of the vessels; it originates mainly by growth of the endothelial cells which lie next the adventitia of both the lymph and blood-vessels (Fig. 497). These cell growths surround the walls of the vessels like a sheath, and, as a growth of the inner endothelial cells also takes place, the lumen of the blood or lymph vessel in question may finally become entirely occluded. The reticulated anastomosing filaments and tubules of the cells usually lie in fibrillar connective tissue, and as a result of hyaline degeneration of the walls of the vessel hyaline tubules are formed having cells in their interior, or the latter is so narrowed by the hyaline degeneration that only hyaline branching cords, bulbs, or spherules without cells are found. Occasionally the hyaline degeneration attacks primarily the cells in the tubules, so that the hyaline cords are surrounded by cells which have not yet become degenerated. The plexiform angeio-sarcoma is really an endotheliosarcoma or endothelioma, and on account of the hyaline cylinders this tumour was once called a cylindroma. Volkmann has recently made a careful study of endothelioma. It is fairly common, and varies a good deal macroscopically and microscopically. The cells undergo various forms of degeneration and show a very variable grouping (alveolar, cylindrical, etc.). The tumours are sometimes encapsulated and sometimes more diffuse, with a very variable energy of growth and capability of recurrence. Some of the endotheliomata, on account of their diffuse growth, are not to be regarded as true neoplasms, but rather as infectious tumours. The endothelioma arises in some cases from the endothelium of the blood-vessels, and in others from the endothelioma of the lymphatics or connective tissue. Küster rightly called attention to the fact that there are hæmorrhagic sarcomata or angeio-sarcomata (endotheliomata) which show

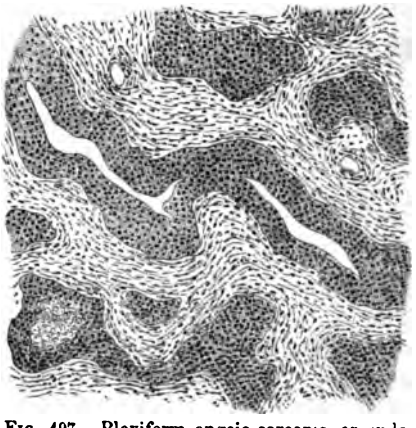

Fig. 497.—Plexiform angeio-sarcoma, or endothelioma, of the thigh. The anastomosing groups of cells are derived in this instance from proliferation of the endothelium of the lymph vessels; they surround the latter like a sheath. In some places the groups of cells, or endothelium, are in solid masses, while in others they have undergone degeneration. × 30.

extensive degeneration of the walls of vessels—i. e., growth of endothelial cells and hyaline degeneration—before a tumour nodule has become developed; they lead to hæmatomata without macroscopically visible sarcoma tissue. In other cases such hæmatomata are followed, months after, perhaps, by remarkably malignant sarcomata. The plexiform angeio-sarcoma or endothelioma is anatomically easily mistaken for carcinoma, and runs a similar course—i. e., it is a markedly malignant tumour, recurs after extirpation, and causes at a comparatively early period an infection of the nearest lymph glands and metastases. Hence some authors have designated the malignant endothelioma as endothelial cancer. This endothelial cancer, consisting of connective-tissue cells, must, of course, be sharply differentiated from epithelial carcinoma. The formation of metastases in endothelial cancer is very characteristic. Groups of cells grow from the primary tumour into the lymph spaces; the secondary nodules are joined together and with the primary tumour by connecting bands which are often visible to the naked eye. The diseased lymph glands are noticeably soft, very much enlarged, and painless; the cells of the endothelioma are most numerous at the hilum, and from here send out fine processes into the medullary substance.

Fig. 498.—Xanthelasma tuberosum. Hæmatoxylin stain. The fat was dissolved by treatment with alcohol and origanum oil, and the specimen enclosed in Canada balsam. × 600.

The *xanthoma* or xanthelasma, a sulphur-yellow or brownish-yellow pigmentation of the skin, is, according to De Vincentiis, Touton, and others, an endothelioma in which fat has been deposited (endothelioma lipomatodes); it grows from the endothelium of the lymphatic vessels. The peculiar colour of the xanthoma is due to the deposit of fat in the cells. The drops of fat are sometimes so numerous and close together in the interior of the cells that the latter are difficult to recognise. After the fat has become dissolved the cells clear up, and in place of the fat drops there are corresponding gaps in the cells (Fig. 498). It occurs in a flat (xanthoma planum) and nodular (xanthoma tuberosum) form, especially on the eyelids, though occasionally it has a multiple character, appearing on different parts of the body, particularly where there are folds of skin (flexor side of joints, axilla, neck, etc.). Now and then the eruption occurs more or less suddenly—in the course of diabetes, for example (xanthoma diabeticum)—at other times symmetrically, probably from tropho-neurotic disturbances. Occasionally it changes into sarcoma or fibroma (sarco-xanthoma, fibro-xanthoma).

The villous sarcoma, the so-called cholesteatoma, which may be encountered on the meninges of the brain, probably owes its origin likewise

to growth of the endothelial cells of the vessels, or of the cells of their sheaths.

Perhaps the psammoma of the brain and orbit described by Virchow also belongs to the endotheliomata. They are characterised by the presence of large amounts of lime concretions similar to the "brain sand" normally present in the hypophysis cerebri. Such concretions are met with in sarcoma, fibroma, and myxoma, and, according to Billroth, are to be regarded as calcified bundles of endothelial cells which are attached to the blood-vessels, though Virchow thinks they are also the result of the calcification of connective tissue.

The melano-sarcoma (pigmented sarcoma) is characterised by the presence of a brown or black pigment which is almost always deposited in the cells, less often in the intercellular substance and walls of the vessels. On section the melanomata are brown, or, if the pigmentation is excessive, black in colour. The pigmented cells sometimes have branches and resemble the chromatophores of the choroid membrane, and others are large, round cells; transition forms between the two also occur. They are among the most malignant tumours, their growth being sometimes very rapid and the number of metastases considerable (see Fig. 499). They are most likely to develop in places where pigment is already present—as in freckles or pigmented warts, for example (Fig. 499)—and most commonly begin on the extremities. The origin of the pigment is doubtful. According to Gussenbauer, it is

a *b*

FIG. 499.—Melanoma of the skin (man seventy-four years old) originating in a pigmented wart upon the back; within six months over one hundred pigmented spots and tumours formed upon the skin. Numerous melano-sarcomata of the pleura, lungs, pericardium, liver, kidneys, and retroperitoneal glands were found (Lücke).

formed from the red blood-corpuscles of the thrombosed vessels, while others think that it is not identical with the pigment resulting from hæmorrhages, but may be due to a special activity of the cells (Birch-Hirschfeld). Schmidt considers the pigment to be hæmatogenous in nature, having passed the hæmosiderin stage and parted with its iron reaction. The general melanosis

that follows the development of melanotic sarcomata of the skin is caused by embolic extension of the tumours (Tietze).

Terrillon observed, in a case of melanosis which ran a rapidly fatal course, an increase in the number of white corpuscles in the blood and a large number of "black bodies." The amount of hæmoglobin in the blood is usually diminished, rarely increased. Melanuria is encountered in rare instances of multiple melanoma, and Zeller found variable amounts of hydrobilirubin, melanin, and melagon in the dark-brown but otherwise perfectly clear urine. The urine in melanosis, when first passed, is clear, but if allowed to stand becomes black, and at times almost the colour of ink. Before death the freshly passed urine sometimes looks like black pitch.

The question of the transmissibility of melanoma has been experimentally studied by Lanz, Tietze, and Jürgens. The latter's inoculation experiments were successful; within two to three weeks melano-sarcomata developed in the peritonæum, and metastases were formed. Coccidia were always present. Lanz injected into a guinea-pig a certain amount of an infusion of melanotic cutaneous nodules, melanotic brain, liver, and spleen. The animal died a month and a half after the injection, and the autopsy showed collections of pigment in many different parts of the body (skin, subcutaneous tissue, muscles, peritonæum, spleen, liver, kidneys, etc.). In this case the pigment must have been formed in the body, as only very little of the colouring matter was injected.

The chloroma is a pale, grass, or brownish green round-celled sarcoma, which, according to the observations that have been made up to the present time, originates in the periosteum of the bones of the face and cranium, and gives rise to metastatic green nodules in various organs, especially the liver and kidneys. Lücke observed a chloroma of the testicle. According to Huber, the green colour is due to small, very refractive granules, which are found in the cells, and which give the micro-chemical reaction of fat. The chloroma is also characterised by the presence of an abnormally large amount of chlorine.

We have already dwelt sufficiently upon the course and prognosis of sarcoma when discussing its different varieties. The duration of the disease depends in general upon the importance of the organ involved. The sarcoma of the brain is the most rapidly fatal, and may cause death in one and a half to two months. Sarcomata of the mediastinum are likewise very malignant, and may prove fatal in a few months by suffocation or paralysis of the heart. The prognosis is most favourable in the sarcomata of the skin, which can be easily extirpated, and of the extremities in case the tumours are removed early enough by operative means. We have already mentioned that sarcoma, especially of the skin, can be made to disappear permanently by the inoculation of erysipelas. Among important diagnostic factors, besides the above-described general characteristics of sarcoma, are its location and the age of the patient. Its favourite location is in muscle, periosteum, bone, nerves, glands (lymph glands, parotid, testicle,

mamma), and it not infrequently develops after an injury. As regards age, sarcoma is most common in middle life, and less so in childhood and old age. It is usually a painless tumour.

The general rule for treatment is to remove the neoplasm as soon as possible. In suitable cases of encapsulated, myelogenic giant-celled sarcoma of bone the anterior half only of the bony capsule may be removed by means of the hammer and chisel or the saw, and the tumour carefully scraped out with a sharp spoon. In sarcomata of the long bones the extremity can usually be preserved, resection in continuity being sufficient. In inoperable cases the inoculation of the erysipelas toxine may be tried. Burns has observed three permanent cures in five cases of this kind, and Coley published an account of nine cases with four cures. Among the latter was a very remarkable case of Bull's: Round-celled sarcoma of the neck, with five recurrences in three years; the entire removal was impossible in the last operation, and a wound twelve and a half by five centimetres resulted, which soon became filled up with masses of sarcoma tissue. Fourteen days later two attacks of erysipelas took place, whereupon the wound rapidly cicatrised. Seven years afterward the cure was found by Bull and Coley to be perfect. Langenbuch has also published an instance of a great number of recurrent sarcomata of the skin which were caused to disappear by this means. One must, however, constantly bear in mind that the patient may die as a result of the inoculation of erysipelas, and hence it is one's duty to warn the patient or his friends of the danger before this procedure is adopted. The various other methods of treatment of sarcoma are described in the Regional Surgery, and in connection with the treatment of tumours in general. The treatment of sarcomata by toxines is described on pages 778 and 779.

§ 129. **The Epithelial Tumours.**—The epithelial tumours include the papilloma, the adenoma, the carcinoma, and the epithelioma.

I. **Papilloma.**—The papilloma results from hyperplasia of the epithelial layer of the skin and mucous membranes, with a corresponding new growth of connective tissue and blood-vessels. It is really a mixed tumour consisting of newly formed connective tissue and epithelium. A distinction is made between a hard and a soft papilloma.

The hard, horny papillomata include, in the first place, warts (verrucæ), which are the well-known growths of the papillæ of the skin and epidermis, about the size of a bean or a pea. They are essentially a product of an overgrowth of the epidermis, which becomes horny. They are inoculable, as proved experimentally by Judassohn, and sometimes develop in great numbers, particularly on the hands. In rare cases a diffuse warty hypertrophy of the cutis occurs—e. g., on the

scalp (Fig. 500). Mention should also be made of the onychoma (hypertrophy of the nails), calluses (clavi) resulting from a circumscribed hyperplasia of the epidermis, and the cutaneous horns (cornea cutanea), which are excrescences on the skin due to a new growth of horny epithelial cells. The cutaneous horns occasionally originate from the sebaceous glands or from open atheromata (sebaceous cysts). They are most common on the forehead and nose in old people. Brinton has collected fifteen cases of cutaneous horn of the penis, besides one that came under his own observation. They sometimes occur in great numbers (Fig. 501), not infrequently being curved, and may attain a length of from twelve to sixteen centimetres or more (see Regional Surgery, § 5). It should be noted that occasionally benign cutaneous horns which consist only of horny epithelial cells develop into carcinomata.

Fig. 500.—Warty hypertrophy of the scalp occurring in a woman twenty years of age (Billroth).

In this category belong also the tumour-like thickenings of the epidermis called keratomata, which are most commonly found on the sole of the foot and the palm of the hand, and are not infrequently inherited by all the branches of a family for many generations (Unna). They result from a thickening of the epidermis, though the whole cutis also takes part in the hyperplasia. They often change into real cutaneous horns or become combined with other new growths like angeiomata (angeio-keratoma). Unna recommends for their treatment the use of a ten-per-cent. ethereal solution of salicylic acid, or the latter made into a plaster.

Fig. 501.—Multiple cutaneous horns, from twelve to sixteen centimetres in length, on various portions of the body of a seventeen-year-old girl (Bäthge).

The soft papilloma is characterised by a soft stroma, a marked vascularity, and a very moderate growth of epithelium, which does not become horny. It occurs on the skin and mucous membranes—for example, of the bladder, rectum, and uterus. The cauliflower excrescence of the vaginal portion of the cervix is a soft papilloma. In the rectum, uterus, and in other mucous membranes, the soft papilloma forms growths which are analogous to the above-mentioned mucous polyps. The polyps which are covered with epidermis, rete Malpighii,

cutis, and hair, and occur in the pharynx, for example, originate, according to Arnold, from strayed embryonic cells and probably belong to the teratomata. The soft papillomata not infrequently change into sarcoma and carcinoma. The condylomata acuminata or venereal warts found on the mucous membrane of the vulva, vagina, and penis belong to the soft papillomata. The broad condylomata (condylomata lata) are papillary growths with a broad base, and often occur about the anus in syphilis.

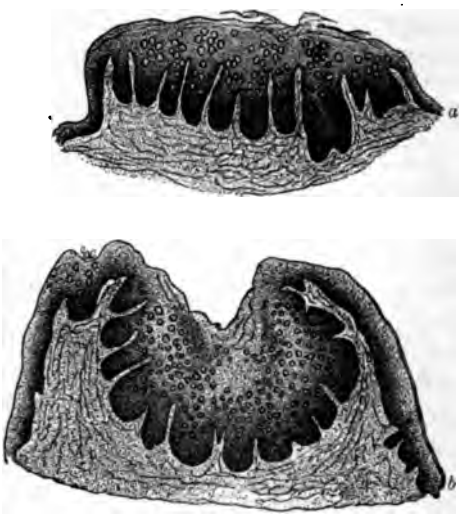

FIG. 502.—Small (*a*) and large (*b*) molluscum contagiosum of the skin. × 25 (Lukowsky).

The various kinds of papilloma should be treated according to the general rules already laid down. Warts should be removed by cauterisation with crude, fuming nitric acid (not chemically pure) after paring off the epidermis with a knife. They are then usually cast off on the fifth or sixth day, or, if not, they may have to be cauterised again. Repeated applications of salicylic or iodoform collodion with a brush, as well as of a paste made with arsenic, are also exceedingly serviceable. By the use of these medicaments the wart gradually drops off in the form of a dried-up eschar. The same treatment may be used for calluses and corns, though they can be removed more simply by the knife after softening them by salt-water baths.

Molluscum Contagiosum or Epithelioma Molluscum.—Authorities differ widely in their views as to the nature of molluscum contagiosum. It is a peculiar skin disease in which there is a development of numerous nodules, varying in size from that of a pea to that of a hazel-nut or larger, generally located on the uncovered parts of the body and on the genitals. The small tumours are epithelial in character, and are said by Hebra to be caused by an accumulation of cells in a sebaceous gland, while Virchow thinks the growth of epithelial cells begins in the hair follicles, and Bizzozero in the interpapillary portions of the rete Malpighii. They contain characteristic bodies, partly free and partly enclosed in cells which resemble swollen starch, and which, according to Leber, are degenerated epithelial cells, although Klebs and Bollinger maintain that they are parasitic (psorosperms, coccidia). In its further growth the molluscum contagiosum develops into a spherical elevation above the skin surface, and may become pedunculated. A cheesy material

can be expressed from the tumour by pressure, which probably consists of the proliferated cells of the rete Malpighii containing the parasites. The disease is contagious, and not infrequently occurs in the form of epidemics, especially in children's institutions. Isolated cases are rarely met with. The nature of the morphological changes in the cells is obscure, and it is still under discussion whether they are caused by degeneration or by parasites. In my opinion, the contagiousness can only be explained on the parasitic theory. The treatment consists in simply pressing out the small tumours with the finger nail; the larger ones may require the use of the sharp spoon. Healing takes place without the formation of a scar.

II. **Adenoma** (*Glandular Tumour*).—The adenomata correspond in their structure to that of glands (Fig. 503), but the term does not include simple hypertrophy of the latter, being used to designate only the true new growths which are separated from the surrounding tissues in the form of circumscribed nodular tumours. Even adenomatous degeneration of an entire organ can be easily distinguished from a general glandular hyperplasia. The adenomata form both hard and soft tumours. Microscopically, a distinction is made between tubulous and acinous or alveolar adenomata. They are very often combined with the formation of cysts. The adenoma is in itself not malignant, but it frequently changes into a destructive form—i. e., it becomes a carcinoma, in that the growing tubules penetrate the surrounding parts, take on an atypical growth, destroy the neighbouring tissues, and, by involving the lymphatics and blood-vessels, give rise to metastases. The commencement of a change like this from adenoma to carcinoma has been called adenoid. There are, however, malignant adenomata, which remain true adenomata, with a distinct separation of the glandular epithelium from the stroma, but which nevertheless cause local destruction of tissue and give rise to metastases. The adenoma of the rectum is an example of this variety. The adenoma is found in various glandular organs, in the skin (sebaceous glands, sweat glands), in the respiratory and digestive tracts, in the genital organs, the mamma, thyroid and salivary glands, liver, kidney, etc.

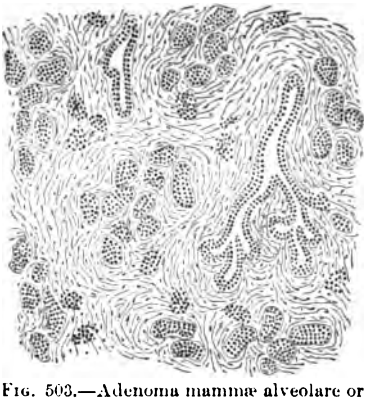

Fig. 503.—Adenoma mammæ alveolare or acinosum. × 30.

The treatment of adenoma consists in prompt extirpation of the tumour, as it is to be looked upon as an early stage of carcinoma, into which it frequently develops. With reference to the technique of the

operation for removal of adenoma of the thyroid (goitre) and of laparotomy for removal of ovarian adenoma, particulars will be found in the Regional Surgery.

III. **Carcinoma** (*Cancer*).—The carcinoma is a tumour that develops from epithelial and glandular cells, destroys the normal type of the tissue in the region primarily affected, is characterised by unlimited

FIG. 504.—Epithelioma of the forehead in a woman fifty-six years old.

growth at its periphery, by the formation of metastases chiefly by way of the lymph passages, and terminates fatally, in the great majority of cases, with symptoms of a general intoxication (cancerous cachexia). It originates from the atypical growth of epithelial cells, the latter forming the main part of the tumour, though every atypical growth of epithelium is not cancer. In inflammatory processes and in the healing of wounds an atypical growth of epithelial cells takes place in the form of cylinders or bulbs, but their growth is limited, and they do not infil-

trate and destroy the surrounding tissues. It is quite different with carcinoma. Here the epithelial cells keep on growing unhindered; they infiltrate the surrounding tissues in the form of cell nests, displacing and destroying them. The cellular cylinders and nests, which are made up of proliferating epithelial cells, lie embedded in a partly old and partly new formed connective-tissue stroma (Fig. 505). The origin of tumours, and particularly of carcinoma, has been discussed on page 770. Cohnheim's theory was also given there. According to Ribbert, carcinoma begins with a vigorous cellular proliferation of the subepithelial connective tissue, and not with a primary advance of the epithelium into the connective tissue. Ribbert claims that in some of the cases the subepithelial inflammation of the connective tissue is tubercular in nature. The growth of subepithelial connective tissue into the epithelium causes the epithelial cells to become separated from their organic connections, and to be displaced into the cellular connective tissue, where they can take on an independent growth. It is this separation of epithelial cells from their normal connections and their displacement among proliferating connective tissue that constitutes, according to Ribbert, the real nature of carcinoma formation. This theory is applicable to a certain number of carcinomata, but not to all (Hauser). The mode of origin of carcinoma is certainly not always the same; the tissue changes may start first in the epithelium or in the connective tissue, depending upon which of these is acted upon by the morbid process. But, wherever it begins, the final result in carcinoma is always the same, and consists chiefly in a fundamental alteration in the biological properties of the epithelial cells, so that they take on parasitic characteristics. The carcinoma cell has become a different one morphologically and biologically from the mother cell from which it was derived. The real nature of these

Fig. 505.—Carcinoma mammæ simplex. × 200.

Fig. 506.—Section through a commencing embolic cancer in a liver capillary resulting from an adeno-carcinoma of the stomach (Ziegler). × 300.

degenerative changes is still unknown. Of late attempts have been made to establish the microbic origin of carcinoma (see page 819, ff). As a result of the unimpeded growth of the carcinoma, or rather of the groups of epithelial cells, the latter invade the lymph and blood-vessels and produce, by means of transported living cancer cells, secondary nodules in the nearest lymph glands, and later in the various internal organs (Fig. 506). This power of forming metastases—in other words, of causing a general infection of the body—is characteristic of cancer. As regards the development of metastases in the lymph glands, it has been shown that the epithelial cells which make their way through the afferent lymphatics into the lymph sinuses multiply by caryocinesis; that they, by their continuous growth, mechanically displace the glandular tissue; and that endothelial cells and lymph cells do not change into cancer cells. Before the appearance of the metastatic elements the lymph glands are usually in a condition of inflammatory hyperplasia. The metastases may be especially numerous if a carcinoma breaks through directly into a large vein and carcinoma cells are carried through the circulation. Goldmann has shown that this occurs more often than has hitherto been supposed.

Thiersch was the first to prove the epithelial origin of cutaneous carcinomata, and Waldeyer afterwards furnished the same proof for carcinomata of the various organs. Other authorities—e. g., Klebs, Gussenbauer, and Rindfleisch—still hold with Virchow to the earlier view, that the carcinoma cells can also originate from connective-tissue cells, particularly from endothelia. Klebs has recently expressed his views regarding this question by saying that the connective-tissue cells and other cells—e. g., the elements of striated muscular fibres—in consequence of "epithelial infection" by the carcinoma cells derived from the pre-existing epithelia, become epithelioid carcinoma cells. We have already said, in discussing sarcoma, that alveolar sarcomata are sometimes difficult to differentiate from carcinomata anatomically, and that many endotheliomata run a similar clinical course to carcinomata.

In the skin the carcinoma arises from the cells of the rete Malpighii or from the cutaneous glands; an infiltration of the corium with epithelial cells gradually takes place, the cells being collected in single groups, cylinders, or nests which lie in a partly old and partly new formed connective-tissue stroma. In the glands a proliferation of the glandular epithelium first takes place, forming an adenoma; then these proliferated cells invade the tissue surrounding the lobes of the glands, where they continue to grow unimpeded. The shape of the proliferated epithelial or cancer cells is not constant, but depends upon the location of the cancer. The cells of an epithelioma of the skin correspond in

general to those of the rete Malpighii, while in a carcinoma of the stomach they have a cylindrical form, etc. Retrograde metamorphoses are very common in carcinoma because the nutrition of the great numbers of cancer cells is insufficient. Hence fatty, mucoid, colloid, or cystic degeneration as well as calcification are of frequent occurrence. Psammocarcinomata of the ovary and mammary gland have been described—i. e., carcinomata with degeneration products resembling

Fig. 507.—Large ulcerating carcinoma of the lower jaw and cheek occurring in a patient suffering from lupus (Esmarch).

Fig. 508.—Pronounced destruction of the face by an epithelioma of the skin (Billroth).

grains of sand, which are scattered through the tumour in a definite way. The degenerative changes in the central portions of a carcinoma and the adhesion to the integument often give rise to an umbilicated drawing in or depression of the skin. Superficial carcinomata, especially those which involve the skin, mucous membranes, or mamma, are extremely apt to break down and form extensive sloughing, punched-out ulcers (Figs. 507, 508). Bleeding not infrequently takes place, manifesting itself in the form of circumscribed hæmorrhages or blood cysts, or, in other cases, a carcinoma may by degrees erode a large vessel, and thus suddenly lead to a profuse loss of blood, which may prove fatal.

Occasionally a primary carcinoma is found in a multiple form. Schimmelbusch has collected these rare cases from literature showing that multiple carcinomata of the skin are the most common, and may develop from a soot or tar eczema, from senile seborrhœa and xeroderma pigmentosum, ulcer of the leg, etc. The multiplicity of carcinomata results from the multiplicity of the irritations and of the embryonic starting points of tumour (Walter). Regarding the devel-

opment of multiple carcinomata by inoculation or implantation from one part of the body to another, see page 820.

The following different varieties of carcinoma can be distinguished:

1. *Flat Epithelial Cancer or Epithelioma.*—The epithelioma of the skin, or cancroid, appears in the form of diffuse thickenings or nodular, warty, often ulcerating, elevations. On section, the alveolar structure can usually be seen with the naked eye and the epithelial nests or cylinders can be squeezed out or scraped from the cut surface with the knife. Some epitheliomata remain superficial, while others grow into the deeper parts. The superficial variety, ulcus rodens, as it used to be called, arises mainly from the rete Malpighii, while the growth having deeper attachments takes its origin to a greater extent from the sebaceous glands.

Epitheliomata also develop on mucous membranes that have a pavement epithelium (mouth, pharynx, œsophagus, vagina, uterus, bladder).

2. *Cylindrical-celled Carcinoma.*—The carcinoma with cylindrical cells is found particularly in the mucous membrane of the digestive tract and uterus; it has a soft consistence and is very likely to undergo a mucoid degeneration.

3. *Carcinoma with Gland Cells (Carcinoma Glandulare).*—This is found in various glandular organs (mamma, liver, salivary glands, kidneys, testicles, etc.), and varies histologically according to the organ affected.

4. *Other Varieties of Carcinoma.*—According to the shape, consistence, and other properties of the cancer the following varieties may be differentiated. The scirrhus is a very hard, tough carcinoma with small and few cancer-cell nests lying in a dense stroma. The soft carcinoma (carcinoma medullare) is the opposite of the scirrhus, being rich in cells and having a soft stroma. The pigmented or melano-carcinoma, like the melano-sarcoma, is a brown or black tumour, which is, however, much less common than the latter. The pigment is likewise situated in the cells.

The so-called giant-celled carcinoma is in some instances made up of true giant cells, while in others the increase in the size of the cells is due to mucoid or dropsical degeneration.

The colloid cancer (carcinoma gelatinosum) occurs especially in the intestine and breast, where it forms a transparent gelatinous tumour as a result of the mucoid or gelatinous degeneration of the cell nests. The carcinoma myxomatodes originates either from the mucoid degeneration of the stroma and often of the cancer cells, or from the combination of a myxoma with a carcinoma (myxo-carcinoma). Occasionally colloid degeneration of the cancer cells gives rise to homogeneous spherical bodies which are found in the cancer nests. Psammocarcinoma is spoken of on page 805.

Fig. 509.—Epithelioma of the lower lip in a man fifty-two years of age. Excision. Recovery.

The external appearance of carcinoma is variable. It sometimes forms circumscribed nodules and warty elevations, as in Fig. 509, sometimes more diffuse, superficial infiltrations and indurations, or ulcers with hard, thickened, and infiltrated edges (Figs. 507, 508, 510), or, finally, papillary cauliflower-like growths (Fig. 511), particularly on the mucous membranes—e. g., on the

bladder, etc. Occasionally the skin, as in the region of the mamma, becomes diffusely diseased, as hard as a board, and infiltrated by a great number of small and large nodules (cancer *en cuirasse*).

Etiology of Carcinoma.—Local irritations of a mechanical and chemical character are very important factors in the production of a carcinoma. Hence one is most likely to develop in those parts of the body where mechanical and chemical irritations commonly occur, as in the skin, lips, mouth, œsophagus, and in other parts of the digestive tract where normally narrow places exist, such as, for example, the œsophagus at the point where it passes through the diaphragm, the cardiac and pyloric regions of the stomach, the sigmoid flexure, the rectum near the sphincter tertius, and the anus. In men, cancers of the skin, lips (almost always the lower lip), mouth, and rectum are the most common; while in women the glandular carcinomata predominate, and those of the mamma and the uterus are especially frequent. This latter fact explains why carcinomata occur more frequently in the female sex than in the male. Out of 7,878 cases of carcinoma, 2,861 occurred in males and 5,017 in females. Carcinoma of the stomach is equally common in women and men, and is very likely to develop from a

Fig. 510.—Epithelioma in a man fifty-eight years of age. Duration ten years.

Fig. 511.—Papillary epithelioma of the left cheek, starting in the mucous membrane of the cheek.

cicatrised gastric ulcer. The epitheliomata of the lips, especially the lower lip in men, having been ascribed to smoking, to frequent irritation from unskilful shaving, etc., and the epitheliomata of the tongue and mucous membrane of the inside of the mouth to the irritation produced by smoking, chewing tobacco, and drinking, or by the sharp edges of the teeth. Out of 77 carcinomata of the lip, 73 occurred in

men and 4 in women, and three out of the four women were smokers (Warren). Out of 245 cases of carcinoma of the tongue, 230 were males (Pennel, Sachs, Bottini). The 100 cases observed by Bottini all occurred in individuals who were very much given to the use of tobacco, including three women. Chewing has been seen to cause carcinoma of the mucous membrane of the cheek and gum in the vicinity of the last molar teeth even in young subjects. Tobacco in its natural form does not appear to be injurious, but rather the substances which are used in the tobacco factories for adulterating it. The epitheliomata of the scrotum, observed in chimney-sweeps and workers in tar and paraffin, are explainable on the same principle. Analogous irritating chemical substances are present in soot, tar, and paraffin, just as in tobacco-smoke, tobacco-juice, and tobacco-ashes—i. e., various products of dry distillation, especially tar, carbonate and acetate of ammonium, pure acetic acid, and carbolic acid. These irritating substances become deposited in the skin of the scrotum, and sometimes give rise to cancer. I observed in a worker in paraffin who had a characteristic chronic paraffin dermatitis, with the formation of scabs and pustules on the hands and forearms, the development of a typical carcinoma with metastases at the site of one of the scabs. Fig. 512 shows the hand of this patient, who finally died of general carcinosis. Two years previously I had removed from the same man a paraffin epithelioma of the scrotum, which did not recur. Characteristic examples of the development of carcinoma from chemical and in part traumatic irritations are the carcinoma of the penis, which occurs almost exclusively in case of a tight foreskin (phimosis), and the primary carcinoma of the gall-bladder in case of gall-stones. Chronic inflammations in various parts of the body often give rise to carcinoma—e. g., ulcers, fistulæ, sequestrum cavities, syphilitic and tubercular processes, etc. Carcinoma also develops in benign tumours—e. g., in warts, sebaceous glands, cutaneous horns, etc. In some cases a single traumatism (blow, kick,

Fig. 512.—Hand of a worker in paraffin, showing chronic dermatitis with a formation of pustules and crusts and papillary growths; carcinoma of the forearm starting from one of these inflamed spots; amputation of the forearm and death from general carcinosis.

etc.) or cicatrix is a sufficient predisposing factor to produce a carcinoma. The carcinomata that form in cicatrices probably develop from epithelial cells inclosed in the scar. According to different authors, the development of carcinoma is favoured by a too plentiful meat diet, as the inhabitants of southern countries, who live largely on vegetable food, and the herbivorous animals, are said, as compared with the carnivora, to suffer very seldom from this disease. A predisposition to carcinoma often appears to be inherited. There are numerous very striking examples which prove the heredity of carcinoma. I need only mention the Napoleon family, and the instance reported by Broca, in which, out of 26 descendants (over 30 years of age) of a woman who died of carcinoma of the breast, 15 developed carcinoma. It is essentially a disease of advanced life. At this period a slowly increasing atrophy of the stroma, in a certain sense, takes place, with degeneration of the elastic fibres, causing the skin, for instance, to become shrivelled and thin, and rendering it easier for the epithelium to make its way into the stroma as a result of mechanical or chemical irritations. A "boundary war," as it were, begins between epithelium and connective tissue, which in carcinoma ends in a victorious entrance of the epithelium into the less resistant stroma. The highest mortality of carcinoma occurs between fifty-five and sixty-five. It is interesting to note that white people are twice as often attacked by carcinoma as colored. Social conditions are also of importance in the origin of carcinoma. It is more common among the higher classes and among country people than among the poor and those who live in industrial centres (R. Williams). With the improvement in the condition of the people in England the malignant tumours (carcinoma, sarcoma) have become more common, and the mortality rate is at present four times larger than it was fifty years ago (Williams). Among vegetarians—e. g., in India—carcinoma is rarer than among the population in England, where meat is usually eaten. The statistics of Nason show that carcinoma has increased of late, particularly in swampy regions with stagnant water, and he considers it possible that the evaporation of stagnant water or soft ground causes infection just as in the case of malaria (see page 819, Importance of Micro-organisms in the Etiology of Carcinoma).

What is the cause of the unlimited energy and power of growth possessed by carcinoma? Hansemann attempted to answer this question in the following way: While it is an established fact under normal conditions that in the indirect nuclear division the chromatin or nuclear fibrils divide into exactly equal-sized groups, in malignant epithelial tumours (carcinoma) a division often takes place into two unequal groups. This asymmetrical nuclear division, which belongs

only to the malignant epithelial growths, is due to the fact that the cell eliminates certain parts of its protoplasm in the same way that the ovum, by expelling the directing or polar globules, frees itself of certain elements that are present in too large quantities. In this way the cancer cells attain an independence like that of the ovum, and to this is due their energy of growth and power of further development as metastases in different parts of the body.

Importance of Micro-organisms in the Etiology of Carcinoma.—In recent times the attempt has been repeatedly made to establish the microbic theory of the origin of carcinoma. Bacteria have frequently been found in carcinomata, and Scheuerlen, in particular, believed that he had found the bacillus of carcinoma, which was afterwards proved to be a harmless saprophyte. Besides harmless saprophytes, the bacteria of inflammation and suppuration (staphylococci, streptococci, and bacilli) are occasionally found in malignant tumours, particularly in degenerated portions. These bacteria are of no importance in the origin of carcinoma, but they sometimes give rise to suppuration and even septic infection. Numerous bacteriological investigations show that micro-organisms (bacteria, fungi, etc.) may be deposited in tumours, even though the latter are not in direct contact with the external air.

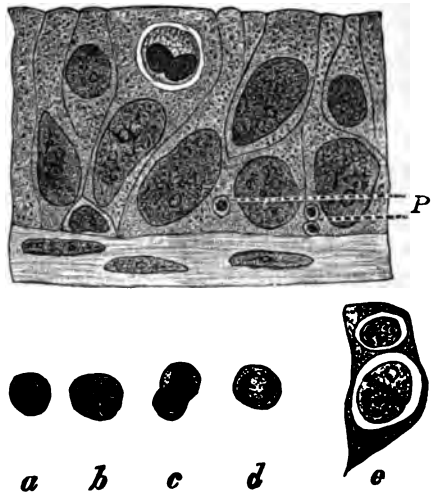

FIG. 513.—Epithelial cells of a cylindrical-celled carcinoma of the rectum containing apparent parasitic bodies. The upper figure, which is magnified 910 times, shows epithelium containing a wandering cell with two nuclei and nine large nuclei; at *P* are seen the three intracellular, probably parasitic, structures; *a–d* show the bodies in question under high power (1,500); *e* represents a larger structure of probably the same nature.

At present the parasitic theory of the origin of carcinoma (by protozoa) is attracting universal interest. The protozoa have already been described as the causes of vegetable and animal diseases (page 282). Darier and Thoma in 1889 discovered, independently of one another, certain parasitic organisms in the epithelial cells of carcinomata of the stomach, rectum, and breast (Fig. 513). Darier classified these as sporozoa (psorosperms). These doubtful bodies are unicellular organisms, 4 to 15 micromillimetres in diameter, consisting of protoplasm and a nucleus. They occur singly or in groups of four to six within the nuclei. They can be stained by the usual methods. The original reports of Darier and Thoma have been followed by numerous other confirmatory reports of different authorities. Some of these regard the organisms in question as sporozoa, and as the exciting cause of carcinoma; others believe only the former, and doubt their etiological connection with carcinoma. A third

[illegible]

cipient; this predisposition is present in individuals having carcinoma. The rarity of successful inoculation of carcinoma from one animal to another of the same species shows that the inoculation of healthy individuals by those suffering from the disease only occurs in exceptional cases.

Carcinoma can thus be said not to belong to the contagious diseases in the usual sense. Contagion is possible, as, for example, in the case of wives with carcinoma of the uterus who give their husbands a carcinoma of the penis; but it really belongs to the rarest exceptions.

The successful inoculations of carcinoma cannot, as has been said, be used as proof of the parasitic origin of carcinoma. They merely have the importance of a successful transplantation of tissue.

Although the parasitic theory of carcinoma has not yet been proved, it must nevertheless be said that there is, *a priori*, no decisive ground against the acceptance of the same. On the contrary, since the recent investigations of Jürgens (page 806) regarding the parasitic origin of sarcoma, I consider the theory very probable; but whether it is applicable to every case of carcinoma it would be impossible to say. The etiology of carcinoma is probably not a simple one, and doubtless various factors enter into it. For the further investigation of the etiology of carcinoma it is advisable to examine portions of living tumour material with a heatable microscope. Under such a microscope peculiar movements have been observed in the interior of the carcinoma cells.

Course, Prognosis, and Diagnosis of Carcinoma.—Carcinoma runs a chronic course extending over months and years. Its varying energy of growth and its location are factors of great importance in determining how rapidly or slowly the disease will progress. In rare instances a more or less acute general carcinosis takes place, causing, in a few weeks, metastases and marked cancerous cachexia. The latter is very much increased by rapid growth of the primary and secondary cancer nodules, by ulceration and sloughing, by stenoses that interfere with the entrance of air or food, by disturbances of digestion, etc. Ulceration is especially prominent in epitheliomata of the skin. Cancerous ulcers are, as a rule, irregular in form, and their edges and bases, as well as the surrounding tissue, are hard and indurated. The superficial ulcerating epithelioma of the skin, the so-called ulcus rodens, runs comparatively the most favourable course, in that it spreads slowly over the surface, has less tendency to involve the deeper parts, and only leads late in its course to infection of the nearest lymph glands. Carcinoma spreads chiefly by way of the lymphatics; the nearest lymph glands become affected first. Embolic metastases caused by the breaking through of a primary or secondary carcinoma into the circulation with general carcinosis are rarer, while in sarcoma they are the rule.

As regards the development of metastatic tumours, the condition of the tissue in which the carcinoma cells lodge is important. The differ-

ent tissues and organs possess a variable predisposition for the further growth of the carcinomatous emboli. It is only in this way that one can understand why it is that metastases sometimes develop only in the bones, and that metastases are very rare in the spleen. Embolic metastases are observed most frequently in the liver in case of carcinomata of the regions connected with the portal system, and then in the lungs, kidney, and bone. The order of frequency in the location of secondary carcinomatous nodules is as follows: lymph glands, liver, lungs, pleura, peritonæum, kidney, bone, spleen. Metastases in bone are frequently observed in the case of carcinomata of the vascular thyroid gland in consequence of a breaking through of the carcinoma into the circulation, and also in carcinoma of the testicle, prostate, and mammary gland. Of 50 carcinomata of the thyroid gland, Hinterstoisser found that 10 were associated with metastases in the bones, and of 20 cases Paget also found the same thing true of 10. On the other hand, Gussenbauer and Winiwarter state that in 903 cases of carcinoma of the stomach, metastases were not found once in the bones, if we except the cases of general carcinosis. The rarity of metastases in the spleen is striking when we consider that pyæmic abscesses of this organ are so common. Out of 753 autopsies on carcinoma of the mammary gland there were metastases in the liver 241 times, and in the spleen only 17 times.

According to Klemperer, the metabolism of cancerous individuals is characterised by a pronounced destruction of albumen, the viscera undergoing fatty degeneration, and the blood showing a marked diminution in its percentage of carbonic acid almost down to one third of the normal. According to Grawitz and others, all the constituents of the blood are diminished in carcinoma. The carcinoma leads to a general intoxication by certain poisonous substances (toxines). The excretion of urea diminishes, as in all malignant tumours, and finally becomes less than twelve grammes a day (Rommelaire, Ransier). According to Müller, the cancerous cachexia resulting from the increased destruction of albumen is similar to that occurring in the febrile diseases and in long-continued malaria, leucæmia, and pernicious anæmia. The cause of the abnormal destruction of albumen in cancerous individuals probably lies in the poisonous action of the products of metabolism of the carcinoma. As a result of the accumulation of these products of metabolism and of the insufficiency of the kidneys, coma and death may supervene (see pages 743, 744).

The *prognosis* of cancer is, as we have already clearly stated, very unfavourable. Complete cures are rare, even when the carcinomata are extirpated very early in their course. As a rule, one recurrence follows another

until the patient succumbs to general carcinosis or exhaustion. We make a distinction, based upon their mode of origin, between continuous and regional recurrences; the former spring from portions of the primary tumour which were left behind at the time of the operation, while the latter (regional recurrences) are to be looked upon as independent new tumours in the cicatrix or its vicinity. The second kind sometimes make their appearance only after the lapse of years. All recurrences which occur later than two years after the operation should be considered, according to Snow, new independent tumours resulting from new injurious agencies.

The *diagnosis* of carcinoma is in general not difficult if what has been said be borne in mind. A differential diagnosis may have to be made from tubercular and syphilitic growths. A careful microscopic examination of an excised portion of the tumour will usually clear up any uncertainty. If syphilis is suspected, antisyphilitic treatment should be begun (iodide of potassium, mercury, etc.), and when the latter disease is present such a method of treatment will be successful, but not in cases of carcinoma.

Treatment of Carcinoma.—The treatment of carcinoma consists in as early an extirpation as possible. During the later stages an attempt should at least be made to check its course and improve the general condition of the patient. In extirpation with the knife as much of the healthy tissue as can be spared should be included, so as to leave no tumour cells behind. The adjacent region with its tissue spaces and lymphatics is more or less filled with carcinoma cells, and hence the difficulty in advanced cases of extirpating the entire growth *in toto*. The nearest lymph glands should hence always be removed; thus, in every amputation of the breast, for example, the axilla should be opened and the glands and all the fat removed, even though no enlargement of the former can be felt from without. After the axilla has been cut into, slightly enlarged lymph glands are often found in cases where they were not suspected. Complete cures sometimes result from an early, careful extirpation of a carcinoma, and if no recurrence appears within one and a half to two years the patient is to be regarded as probably entirely freed from his disease. I have, however, occasionally seen recurrence take place four to five years after the first operation. One generally occurs sooner or later, and after extirpation of this, the carcinoma very frequently reappears in a still shorter time, making it seem in many cases as though recurrences were hastened and increased in virulency by each succeeding operation.

The different methods of operation for carcinoma with the knife, galvano-cautery, thermo-cautery, etc., are described in the chapters on general surgical technique, and the extirpation of carcinomata in different parts of the body—the skin, breast, mouth, stomach, intestine, uterus, etc.—is described in the Regional Surgery. Nussbaum has recommended for suitable cases the extirpation of carcinomata by means of

the thermo-cautery. It is claimed that recurrences are not so common after this method on account of the more intense reaction of the wound and the firm scar. For the same reason Bougard and others have recommended again cauterisation with caustic pastes (chloride of zinc, caustic points, see page 777). Generally speaking, the thorough removal of the carcinoma with the knife is the most effectual method of operation.

The treatment of inoperable carcinomata is symptomatic. According to the nature of the case, a trial may be made of the various methods already mentioned in connection with the treatment of tumours in general. These include, in addition to a general strengthening regimen, parenchymatous injections, the arsenic treatment, and circumcision with the thermo-cautery in order to diminish the growth, pain, and final sloughing of the carcinoma. In sloughing cancers, use may be made of the sharp spoon, thermo-cautery, and dressings filled with deodorizing substances, such as acetate of aluminium, carbolic acid, bichloride of mercury, iodoform, and naphthaline. Narcotics in the form of subcutaneous injections of morphine are often indispensable. The inoculation of erysipelas has already been spoken of on page 778. Czerny saw two cases of recurrent carcinoma cured by inoculation of erysipelas; the duration of the cure was two and six years respectively. For the description of Emmerich's curative serum and Coley's fluid, see pages 354 and 778. It is frequently necessary to perform an operation for the treatment of the sequelæ of an inoperable carcinoma; a tracheotomy may be required, for example, in carcinomatous stenoses of the larynx, or the formation of an artificial anus in carcinoma of the intestine. Whether the growth of the disease is influenced by the transplantation upon it of healthy skin (Goldmann) cannot as yet be definitely decided.

For other methods of treatment, including the use of arsenic and numerous other remedies, see page 778. Further methods of treatment are as follows: Clay (Birmingham) speaks well of the local and internal action of turpentine (in the form of the essence made by Southall and Barclay in Birmingham, two teaspoonfuls three or four times a day, with pills of sulphur and sulphate of copper, etc.; also local injections into the tumour). Denissenko reports good results from the use of extractum chelidonii (injections are made into the carcinoma every three to five days of one to two hypodermic syringefuls containing either equal parts of the extract and glycerine and distilled water, or two parts of the extract with one part each of glycerine and water; internally, one and a half to five grammes are given, or the ulcerations are packed or coated with two parts of the extract and one part

glycerine). Other remedies are: Glycerine alveolo juice (a euphorbiaceæ) and resorcin locally; decoction (Zittmann's) internally, calcium carbonate and condurango bark internally and locally—all of which are probably without real value. Adamkiewicz has made use of a substance called by him cancroin, which consists of the poisonous products of cancer tissue. As the general use of cancroin is attended with practical difficulties, he recommends a substance with a similar action called neurin ($C_2H_3N(CH_3)OH$), which is used in the form of hypodermic injections in doses of fifteen centigrammes to one gramme a day. Nothing definite can be said at present about the real therapeutic importance of this remedy, but I doubt its value. Snow, at the cancer hospital in London, recommends the opium pipe as a palliative measure in inoperable carcinomata, and also as a preventive against recurrences. Esmarch and others have recommended for cancer patients a diet consisting of but little nitrogenous material.

§ 130. **Cysts—Atheromata, Teratomata, Cyst-formation in Different Tumours.**—The formation of cysts takes place, as we have already said, in many different kinds of tumours in consequence of softening, especially in adenoma (cysto-adenoma), fibroma (cysto-fibroma), and sarcoma (cysto-sarcoma). The proliferating cystoma of the ovaries, kidneys, or mammæ, in which a new production of cysts takes place, belongs to the class of the true cystic tumours. But, in the main, these proliferating cysts are adenomata; a proliferation of cells first occurs, and, secondarily, the formation of cysts as a result of mucoid and colloid degeneration of the cells. This continues, until finally very large tumours are developed, particularly in the ovaries. Cystic goitres also begin as adenomata.

Fig. 514.—Cysto-sarcoma of the femur (Busch).

Bone cysts are, as a rule, either enchondromata, fibromata, or sarcomata, which have undergone cystic degeneration (Fig. 514), or true proliferating cystic tumours. To the latter belongs that cystic degeneration which often simultaneously attacks all the bones of the body, and is perhaps to be regarded as a constitutional disease. Bramann found a multiple formation of cysts in a great number of the bones of a woman thirty-four years old, who had osteomalacia. Many bone cysts are probably due to inflammatory processes or hæmorrhages (Schlange). The soli-

tary cysts of the long bones (Fig. 514) occur most commonly in the femur. They develop usually in the medulla at the ends of the diaphysis; the surrounding tissue usually consists of tumour, either chondroma, fibroma, or sarcoma, so that the cysts are to be explained as a softening process within the tumour in question. The solitary bone cysts have in general a favourable prognosis; they can be completely extirpated, although clinically they bear some resemblance to sarcoma. Cysts of the long bones lead to curvatures and fractures of the same. The cysts of the jaw and teeth (Fig. 515) arise either from the periosteum or from the dental follicles as a result of disturbances of development. Here also the proliferation of cells takes place first, and then a progressive formation of cysts follows. A large number of cysts, originating in a great variety of ways, are congenital; these have been described very fully by Lannelongue and Archard. Other cysts are due to parasites, such as *Echinococcus* and *Cysticercus cellulosæ*, and are found in various organs of the body.

Fig. 515.—Proliferating follicular dental cyst of the lower jaw in a peasant thirty-two years of age (Bryk).

The contents of the cysts are serous, mucous, or bloody. A distinction is made between simple and compound or multilocular cysts. The interior of the latter is divided off by septa, and, in some instances, new cysts form in the walls of the old ones.

The retention cysts do not belong to the true tumours, as in these cases an abnormal new growth of cells does not occur, but only an accumulation of secretion. With Virchow, we divide the retention cysts into (1) mucous cysts, (2) follicular cysts, and (3) retention cysts starting in the excretory duct or the acini of large glands. Mucous cysts, which result from the retention of the secretion of the mucous glands, are found

Fig. 516.—Woman, fifty-nine years of age with sebaceous cysts of the scalp; a typical epithelioma developed in one cyst which suppurated.

especially in the mucous membrane of the lips, the cheeks, the antrum Highmori, the respiratory and digestive tract, the vagina, the uterus, etc. The follicular cysts include the *comedones*, those well-known little spots in the skin, often of a black colour, which are plugs or secretions in the hair follicles, and the *milium* resulting from a similar accumulation of secretion in the sebaceous glands. The atheromata or sebaceous cysts are retention cysts of the hair follicles. The latter continue to form their secretion, and consequently the sac becomes more and more tense; and thus are developed in the skin the well-known tumours which vary in size from that of a small pea to that of a fist or a child's head, and contain epidermis, fat, and crystals of cholesterin. A second variety of atheroma is situated not in the skin, but deeper down in the subcutaneous tissue. These deep subcutaneous atheromata are probably the result of separated embryonic remnants of skin tissue which contain sebaceous glands or groups of epithelium belonging to the epidermis. In the latter case they might be called epidermoids (Franke). Franke thinks that atheromata are not retention cysts of the skin follicles, but represent true new growths which have sprung from embryonic cells. The atheromata sometimes gradually break through the integument, and become complicated by inflammation, suppuration, or even epithelioma (Fig. 516). Hence extirpation of atheromata is always indicated. Cutaneous horns occasionally develop from open atheromata with fistulæ.

Among the retention cysts which arise from the excretory ducts or acini of large glands may be mentioned the retention cysts of the liver, the mamma, and the kidney; also the so-called ranula under the tongue near the frenum resulting from the closure of the excretory ducts of the submaxillary and sublingual glands, and particularly of the Blandin-Nuhn glands—two mucous glands situated near the tip of the tongue.

Cysts are, moreover, found in structures which do not persist after the birth of the fœtus; examples of these are branchiogenic cysts of the neck, cysts of the urachus, etc.

We have already mentioned the occurrence of blood and lymph cysts due to a gradual dilatation of blood- and lymph-vessels.

By cholesteatoma is meant either an atheroma or a dermoid cyst, with characteristic, often silky white contents which are made up of fat, cholesterin, and groups of cells which shine like mother-of-pearl. The cholesteatomata are found especially in the brain and its meninges; also in the ovaries, in the subcutaneous cellular tissue, and in bone (petrous portion of the temporal). According to Eppinger and others, the cholesteatomata are essentially endotheliomata (see page 803). Glaeser examined one which was found on the base of the brain, and came to the conclusion that the cells of the cholesteatoma develop from the endothelia of the lymph spaces of the arach-

mod by growth and concentric division. Kuhn is disposed to think that the cholesteatomata of the ear are principally congenital in origin. Politzer found small rounded bodies in the mucous membrane of the ear which increase in size and lead to the formation of these tumours. The suppuration and sloughing which accompany cholesteatomata of the ear are secondary conditions, and not, as Habermann thinks, the cause of their development. These sequelæ lead not infrequently in cholesteatomata of the ear to death of the patient, and hence Kuhn emphasizes the necessity of a radical removal by osteotomy, if it is required, of the portion of the bone in question, mastoid process. The etiology of cholesteatomata of the middle ear and the meninges is probably complex; some of the cases are certainly endotheliomata, while others are the result of a simple proliferation of epithelial cells, or a change of epithelial cells into epidermis. The etiology of cholesteatomata has an extremely interesting bearing upon the etiology of tumours in general, showing, as it does, that tumours can arise from the cells of the mesoderm which correspond exactly to those that originate from epithelium.

The treatment of cysts depends largely upon their location and their cause; it consists in extirpation, aspiration, incision, parenchymatous injection of various fluids, such as absolute alcohol with or without tincture of iodine, etc. (see page [illegible], Treatment of Tumours in General). The treatment of cysts of the different parts of the body is described in the Regional Surgery. Sebaceous cysts are either extirpated with the overlying skin, or an incision is made over the tumour, the latter separated on all sides with a probe or narrow flat instrument from the surrounding tissue and then removed *in toto* without opening the sac. One should be sure to remove the entire cyst wall. Another method is to make a small incision at the base of the cyst, separate the latter from its surroundings by a probe, and then lengthen the incision sufficiently to remove the tumour. The easiest way usually is to divide the cyst wall in the skin incision and extract the two halves with a forceps.

There exist also congenital tumours or malformations which are made up of a great variety of tissues. They include cysts, the so-called monstrosities, in which one embryo is rudimentary and united to the other, and dual monsters which have taken place in a single ovum. All sorts of structures have been found in congenital tumours and cysts. A tumour discovered in a congenital omphalocele consisted of a body that resembled an eye, which was similar to one found in Hammond and Baumgarten in an human eye. A very [illegible] made an examination of teratomata of the testicle, he believes that they are not the result of the incision of embryonic [illegible] in a normal inflammatory formation of the testicle. The human testicle is the point of origin of the tumour. In large [illegible] of the testicle [illegible] cystic tumours of the testicle [illegible] The

embryonic cystomata of the testicle are, according to Kockel, entirely analogous with those of the ovary, and represent rudimentary parasitic fœtuses. (For further particulars concerning teratomata of the testicle and ovary, see Regional Surgery.)

The dermoid cysts also belong in this class; they have an inner wall which is analogous to the skin, and may occur in organs where skin is not normally present. They are most commonly found in the ovary, and also in the peritonæum, neck, orbits, nose, and in the sacral and coccygeal regions. The wall of the cyst consists, as we have said, of epidermis and corium, with sebaceous glands, hair follicles, and less often sweat glands. The contents usually consist of a fatty, yellowish or whitish, greasy mass, together with hairs, cartilage, bone, and even teeth. In very rare cases, brain, nerve, and muscle tissue or structures resembling extremities have been found. Occasionally the contents are oily (oil cysts). Kocher and Streit have laid emphasis upon a peculiarity possessed by these tumours—when not filled too full—of retaining for a considerable length of time any change of form which is given them. This is due to their homogeneous cement-like contents. If epithelial cells and masses of fat are mixed with a large amount of hair, a peculiar crepitation may be felt on palpation of the tumour (Kocher). The dermoid tumours develop from stray cutaneous cells which have been inverted, as in the closure of embryonic clefts. At the same time cells of the entoderm may become displaced or separated.

Implantation Cysts.—Cysts sometimes occur on the fingers and toes, and more rarely in other parts—e. g., between the cranial bones and the dura as the result of traumatisms. They are caused by the proliferation of epithelial cells which have become displaced by traumatism (Réverdin, Kauffmann, Garré, etc.). There is a connective-tissue sac which contains epithelial pearls, or, in the case of large tumours, a grumous or pulpy material similar to that contained in sebaceous cysts. Giant cells are found particularly in the presence of foreign bodies (Bohm). These cysts can also result from the proliferation of displaced groups of fœtal cells, as, for example, in the formation of the interdigital furrows (Labouyle).

Polypous appendages are sometimes found upon different parts of the surface of the body. They are to be looked upon as abnormal displacements of tissue or malformations depending upon an imperfect closure of embryonic clefts. Such tumours or cutaneous appendages, occasionally containing cartilage, are found in the vicinity of the lines of closure of the dorsal or ventral clefts, or near the face, ears, neck, anal region, or the rhaphe of the perinæum (Chiari).

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